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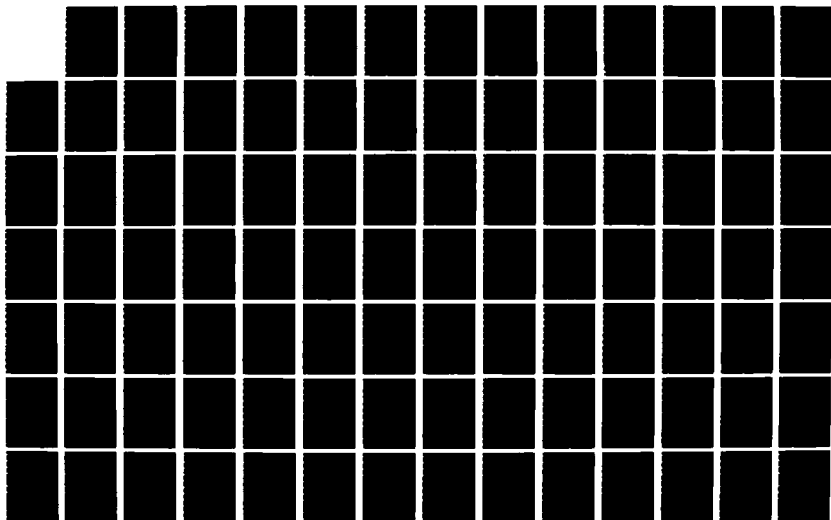
DETECTION OF REMOTE MINEFIELDS PROJECT PLAN I(U)
ENVIRONMENTAL RESEARCH INST OF MICHIGAN ANN ARBOR
15 DEC 78 ERIM-138300-4-T DAAK78-78-C-1198

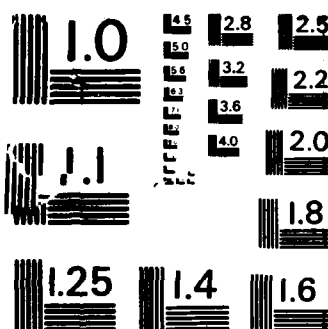
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EXECUTIVE SUMMARY

The objective of the minefield detection project is to determine the effectiveness of remote sensing systems and other methods of detecting and identifying mines, minefields, minelaying equipment, or minelaying operations, and to recommend continuing effort on the most promising methods. This document presents detailed plans to be implemented in conducting this research and development program. This first project plan (Plan I) defines the work to be performed during the contract period with primary emphasis on the first year's effort.

The project effort will concentrate on the European Theater of Operations. The terrain of interest is the West German border areas which are generally exemplified by flat plains to the north and rolling terrain to the south. Primary emphasis will be placed on detecting and identifying anti-tank (AT) and anti-vehicular (AV) mines, and will be directed toward hasty mining and minefields associated with tactical offensive operations (i.e., surface mines). Minefields may be detected by both direct observation or by inferential observations, and both approaches will be investigated.

Work under the project concerned with each of the concepts to be investigated will be performed in a sequence of four major tasks: (1) identification and screening of promising techniques; (2) preliminary systems analysis and definition of experimental or other data acquisitions systems; (3) acquisition of critical data through experiment, literature survey, or access to SCI; and (4) evaluation of conceptual systems for technical and military usefulness.

Four major scenarios for Soviet mine warfare operations have been adopted for analytical purposes. These scenarios result in the use of mines for (1) protecting the most exposed enemy flank during meeting engagement; (2) protecting shoulders during breakthrough; (3) blocking

enemy withdrawal, and (4) supporting a prepared defense. The first three scenarios are for offensive operations and are characterized as hasty operations with mines being in place a relatively short time. These scenarios have the following technical implications. Both surface and buried minefields must be explored. The sensor/carrier vehicle combination ideally should have quick reaction time, and a day/night, all-weather capability. Rapid transmission of information to the local unit commander is required. Finally, the sensor/carrier vehicle combination must not be unduly vulnerable to enemy actions.

Screening of the various technical opportunities so far considered, based on these technical implications, has led to the assignment of highest priority to further consideration of six specific techniques:

- (1) Aerial photography,
- (2) Millimeter and submillimeter wavelength radar,
- (3) Inferential detection,
- (4) Acoustic/seismic methods,
- (5) Ultra-high resolution and multispectral synthetic aperture radar systems,
- (6) Infrared active scanner, including 3-dimensional capability.

During the coming year, other technical opportunities already suggested as well as new ones derived from Task I effort will be identified and screened to add to the list already selected for high priority investigation.

For the experimental acquisition of data on minefield detection, a test installation will be prepared at a location about 20 miles east of Ann Arbor, near where the ERIM Aircraft Facility is located.

For flight testing various types of sensors, a set of two or three test arrays will be installed. Each array will be a rectangle 300 m long by 250 m wide divided into a number of rectangles. Some rectangles will contain surface mines or buried mines of metal or plastic, installed

by various methods, and in various patterns. In other rectangles, various types of minelaying vehicles, fences, simulated field fortifications, etc. will be placed to represent typical battlefield conditions.

Aerial Photography

Further investigation of aerial photography (including satellite photography) involves an exploration of SCI to ascertain its applicability to the detection of minefields. Upon completion of this exploratory effort under Task I, a decision can be made by the time of the third meeting of the Expert Working Group (EWG3).

Millimeter and Submillimeter Wave Radar

Further identification and screening of this type of radar will be based on past and current experience at ERIM with this type of system. Preliminary modeling and analysis will result in estimates of mine detectability. The recommendation, expected to be available by EWG2, will call for either discontinuation of further effort in this direction or further analysis and data acquisition effort on one or more specific concepts.

Inferential Detection

The prudent evaluation and use of indicators based on certain events or actions by the enemy for inferential detection has applicability to the detection of minefields. Given certain scenario situations, it may be possible to ascertain the probable locations of minefields through an analysis of the actions the enemy takes prior to or during offense, blocking or defense operations. Possible indicators include terrain characteristics, evaluation of intelligence reports, a knowledge of enemy tactics, observation of areas of minimum traffic, identification of minelaying activities, etc.

The effort on inferential detection during Plan I will concentrate on identifying indicators likely to be helpful for minefield detection, searching for such indicators in applicable imagery, and assessing the

utility of radar or electro-optical sensors for detecting these indicators.

Data inputs from aerial photography SCI are expected prior to the second meeting of the EWG (EWG2). An interim report of findings will be presented at this meeting. Initial findings resulting from analysis of spotlight radar and active infrared scanner data will be reported at EWG3, together with further results of the aerial photography explorations.

Acoustic/Seismic Methods

Further consideration will be given to seismic and acoustic sensors for the mine detection mission. This study will include not only consideration of the sensors themselves, but of the various methods available which might be used for emplacing them, including airdrops, artillery shells, and remotely controlled ground-based vehicles.

Two concepts will be given particular attention. Portions of the U.S. Army program called REMBASS (Remote Battlefield Surveillance System) may be applicable to detecting the laying of minefields. REMBASS type sensory equipment would be keyed to distinguishing signatures of such an operation. A second method for detecting minefields depends on the use of Fuel-Air Explosive (FAE) weapons. The presence of suspected minefields could be verified by dropping FAE weapons individually on them.

The immediate effort on these acoustic-seismic techniques involves preliminary analysis under Task II, with initial results reported at EWG2, and a critical decision point reached by EWG3.

Radar

The spotlight mode of radar operation differs from conventional synthetic aperture radar strip mapping by providing ultra-high resolution, selected "spot" coverage, and data collection over a wide angle.

Under Task III, Plan I, a flight will be made of the ERIM spotlight radar in the CV580 aircraft. The flight will be made in late Spring or early Summer, consisting of three passes over each of the three sites.

First processing of the spotlight radar flight test data will produce images of the arrays with maximum resolution to determine whether shape recognition of individual mines can be accomplished. The analyst will also attempt to identify patterns of terrain disturbance caused by the minelaying operation. In addition, detection and identification of minelaying equipment and other man-made features located in the test array will be attempted. If individual mines can be detected, mine cross sections and clutter statistics will be obtained as a basis for establishing reliable models and computing probability of detection.

The spotlight radar data will also be processed at degraded resolution to ascertain whether lower resolution radar can effectively be used for detecting mines or minefields.

In parallel with the flight tests, laboratory measurements will be made to determine mine cross-sections at L-band. L-band is of interest because the attenuation due to soil moisture is much less than at X-band, and the reflected signals from buried mines and from soil disturbances may be higher.

Using the mine cross section models, ERIM will make predictions on minefield detectability at both X- and L-bands.

The experimental program just described will become the basis for further definition of work in spotlight radar. Also, processing spotlight radar with degraded resolution will lead to a decision on the value of X- and L-band radar. A favorable decision would lead to a flight test of the ERIM X-L radar. This decision will be made at the time of EWG3, and will be incorporated in Plan II.

Infrared Systems

Previous studies have given considerable information on the utility of thermal infrared passive scanners. Under the current program, it is desirable to investigate the usefulness of the active scanner. With the active scanner, detection is not dependent on a knowledge of the thermal history of the mine. This is a distinct advantage where hasty minelaying is involved. Furthermore, active scanners may be able to detect man-made objects by means of their specular reflections, and are useful for both day and night operations.

The test program will use a modified AVD-4 system, capable of illuminating the object and detecting it at both 1.06 and 10.6 μm . In addition, the scanner is capable of observing mine shape in 3-dimensions, height as well as plan view. A special test setup will be made in which typical mines are located along the ground and observed from the scanner mounted on the roof of the ERIM Aircraft Facility hangar building. The test data will be analyzed to determine whether individual mines are detectable, to measure mine reflectivity as a function of aspect angle, and to measure reflectivity of the terrain background. The 3-D data will also be processed to form images, and the images will be studied to determine whether mine visibility is enhanced by the 3-D process.

Some preliminary information on the use of the active scanner will be available from the rooftop experiments at the time of EWG3. However, adequate data for critical decision making is not expected to be available until December 1, 1979. These decisions will be concerned with the use of the active scanner at two frequencies and the use of reflectance data and 3-D data.

Management Plan

In order to accomplish the technical results described above, a management plan has been prepared. A detailed work description is given

for accomplishing mine detection program objectives during Plan I, extending from 1 January 1979 to 5 September 1979, at which time Plan II will be submitted to the sponsor for review and approval. Schedules are included in the report for the various tasks and subtasks, delivery of reports, and holding meetings. Significant milestones and timing of critical decisions are noted in the schedules. Personnel, and major items of facilities, equipment, materials, and services needed for the work are also itemized.

1
OVERVIEW

1.1 SCOPE OF PLAN

This document presents detailed plans to be implemented in conducting a research and development program on methods for detecting and identifying remote minefields. A statement of the objectives and work to be performed under this program are detailed in Section F, Description/Specifications of Contract DAAK70-78-C-0198. The plan defined in this document is submitted in accordance with the requirements of Paragraph F.2.e of Section F. That paragraph requires the submission of a recommended Project Plan, identifying promising detection techniques, unresolved issues, and investigations needed to resolve these issues. The first Project Plan defines the work to be performed during this contract with primary emphasis on the first year's effort, and will be followed by a second Project Plan due on 5 September 1979. After review of the Expert Working Group and subject to modification and approval by the sponsor, this first plan constitutes the detailed plan to be implemented in achieving the program objectives.

This plan covers primarily the activities of ERIM during the program and will be performed in cooperation with the sponsor and system contractor.

The objective of this project is defined in Section F, included in the contract, as follows:

1. Determine the effectiveness of remote sensing systems against minefields; determine under what conditions of weather and terrain they are effective and how they can be most effectively employed to detect either minefields or mining activity.

2. Evaluate effectiveness and perform further investigations, where appropriate, of other systems for detecting minefields remotely.
3. This effort contemplates development of hardware or new application of existing hardware, but does not provide for an analysis of more conventional "military" approaches such as reconnaissance in force or interrogation of prisoners.

The program is primarily directed toward providing sufficient reliable data and information to enable the formulation of plans for continuing development and implementation of the most promising opportunities. The final recommendations will be specifically concerned with the development of hardware or new applications of existing hardware and defining their expected military usefulness during combat operations.

In order to remain within the limits of time and funding for the project, the plan has been prepared in accordance with certain constraints, guidelines, and interpretations which have been adopted with the approval of MERADCOM.

The Project Plan gives detailed information on plans to be implemented during the first year of the contract, particularly in connection with tests of systems previously studied by ERIM. Since the future program will depend heavily on results obtained during the first year's effort, definition of plans for work beyond that time can be indicated only in general terms at the present time.

A technical approach which otherwise appears to be the most favorable for implementation may fail to accomplish its intended purpose for reasons not directly related to technical capability. In making its recommendations, ERIM will, therefore, not only specifically identify major areas of technical risk, but will also include operational, financial or other risks associated with each technical approach.

1.2 EMPHASIS OF TECHNICAL APPROACHES

Although consideration will be given to a wide variety of techniques, equipment, operational situations, and geographic locations, the project effort will concentrate on certain operational conditions considered to have the highest priority.

The European Theater of Operations, as exemplified by the West German border areas, represents the geographic area of highest priority in the study. Initial concentration will be placed on rural areas typical of this region. Test arrays will be located in terrain representative of the areas mentioned.

Primary emphasis is to be placed on detecting and identifying anti-tank (AT) and anti-vehicular (AV) mines.

The types of mines and their associated minelaying operations will be selected in accordance with information available on Russian equipment, tactics, and doctrine. It is understood that their tactics emphasize the use of hasty minefields, laid with the use of trucks, tanks or helicopters for offensive operations. Primary emphasis of the investigation will, therefore, be directed toward hasty mining and minefields associated with tactical offensive operations (i.e., surface mines). Deliberate mining and associated types of minefields (i.e., buried mines) are also of interest and will be given secondary emphasis. These minefields are often laid in conjunction with defensive operations.

Minefields may be detected by direct observation or by inferential observations. Various techniques may be directed toward the detection of individual mines, complete minefields, minelaying equipment, or minelaying activities. The contract previously performed by ERIM for MERADCOM was principally concerned with remote direct observations of minefields and minelaying operations. A major portion of the planning effort contained herein is concentrated on developing requirements for test arrays and testing program which will provide the critical data needed in order to evaluate the

usefulness of remote direct observations in minefield detection. Concurrently with the above, we plan to explore the potential of inferential observations for minefield detection. The positive results of these investigations will be incorporated into the requirements for test arrays and test programs as they develop. One specific approach to performing inferential observations is based on the observation of trafficability. Minefield detection operations need not be expended on areas which are found to be inaccessible to vehicle traffic. Other inferential indicators, such as areas of high or low levels of enemy activity, location of ancillary operations and equipment will be explored.

During the period covered by this plan, the project will proceed with the acquisition of critical data leading to the demonstration of feasibility of a number of technical approaches already studied under previous projects and selected for further investigation. In addition, the work to be performed under Plan I will include the identification, screening, and analysis of other promising techniques for minefield detection which will be added to the list of technical approaches on which further effort is to be expended.

1.3 TASK STRUCTURE AND PROGRAM ELEMENTS

Work under the project concerned with each of the concepts to be investigated will be performed in a sequence of four major tasks:

- Task 1. Identify and screen most promising techniques for minefield detection.
- Task 2. Provide technical support to preliminary systems analysis of candidate systems and define experimental or other data acquisition programs.
- Task 3. Acquire critical data.
- Task 4. Provide technical assistance to the systems analysis contractor in evaluation of conceptual systems for technical and military usefulness.

Figure 1-1 shows the major elements of technical accomplishment of each of the four tasks. A more detailed description of this task structure is given in Section 2. Although the task sequence and individual task elements are similar for each concept to be investigated, the various concepts have reached different stages of advancement as a result of previous effort on them. In essence, a group of concepts has already reached a stage where critical data needs can be identified, while a separate effort will be devoted to initiating the consideration of other concepts. It is, therefore, appropriate to consider that the effort devoted to the program during the period covered by the Project Plan consists of four basic program elements:

1. Carry out selected data acquisition programs recommended in previous contract performed by ERIM.
2. Conceptually define means for other remote and close in min-field detection systems.
3. Carry out data acquisition program for Item 2.
4. Evaluate resulting promising minefield detection systems for technical and military usefulness.

1.3.1 DATA ACQUISITION PROGRAMS RECOMMENDED IN PREVIOUS CONTRACT

In this first Project Plan, we will describe the techniques and equipments selected for further effort and the rationale for selecting each technical approach.

At this early stage, several of the specific technical approaches selected are derived from the past work done in this area by ERIM Under Contract DAAK70-77-C-0178 from MERADCOM. The general recommendations contained in the final report on that project have been converted to a specific program of data collection and analysis, with much of the effort concentrated on field experiments to collect basic data on sensor and data processing equipment performance for the technical approaches selected.

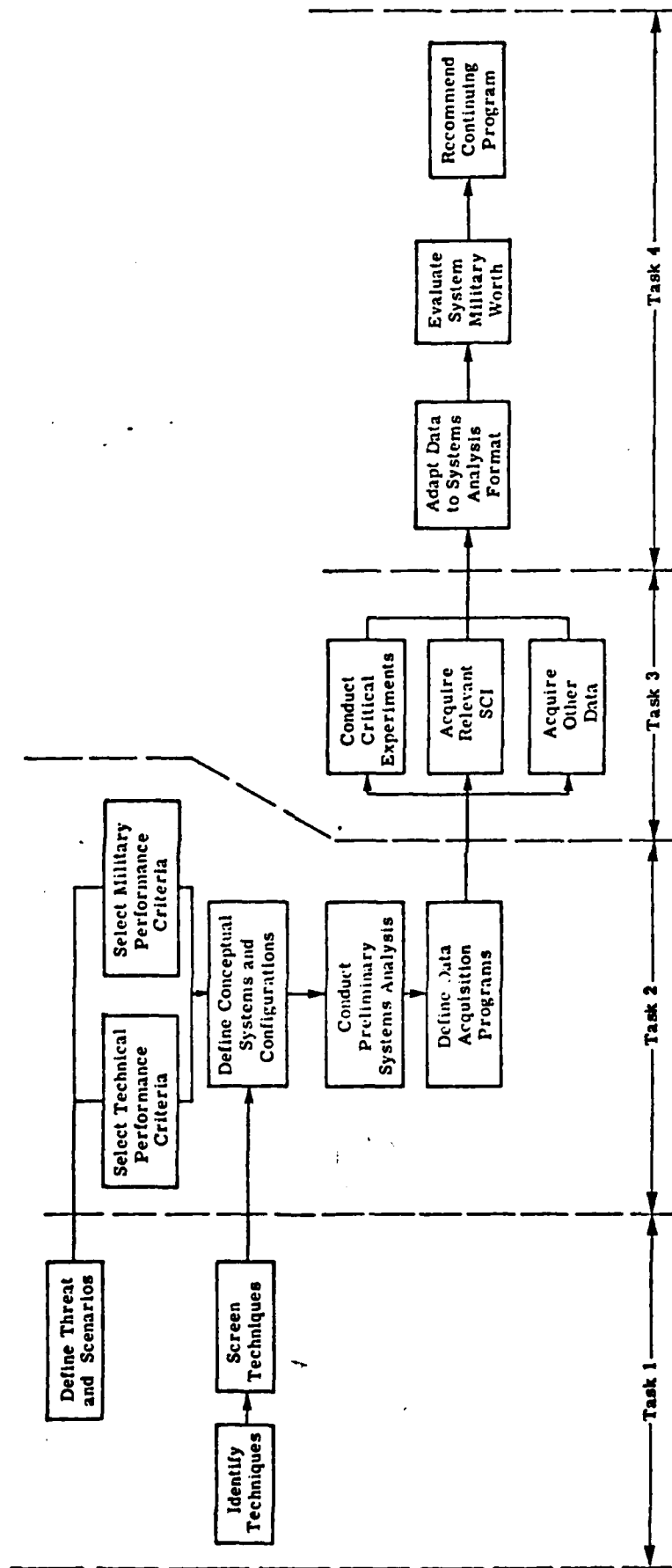


FIGURE 1.1. ELEMENTS OF TASK STRUCTURE

In parallel with the early effort toward exploiting the technical approaches already considered in past work, ERIM will assist the system contractor and the sponsor in the task of defining the threat and scenarios which should be considered in the analysis and testing of various technical approaches. ERIM's special interest in the results of this effort is to assure that its data acquisition plans will give results representative of system performance under realistic battlefield conditions.

1.3.2 IDENTIFICATION AND CONCEPTUAL DEFINITION OF OTHER CONCEPTS FOR REMOTE AND CLOSE IN MINEFIELD DETECTION SYSTEMS

An effort is also planned to establish other conceptual systems capable of responding to the defined threats. The system contractor will cover the operational and doctrinal aspects of this phase of the work, while ERIM will be responsible for translating these aspects into technical factors governing choice of sensor selection, carrier vehicle, and system definition.

In parallel with the definition of specific efforts based on past work in this area, the plan covers ERIM's effort toward gathering more information on techniques derived from review of Sensitive Compartmented Information.

1.3.3 DATA ACQUISITION FOR NEW CONCEPTS

Once the additional concepts have been defined, they will be analyzed to determine the need for data to evaluate them. Specific task effort to acquire the needed data cannot be defined at this time, but will be incorporated into the plan when appropriate.

1.3.4 EVALUATION FOR MILITARY EFFECTIVENESS

Recommendations on mine detection techniques and equipment will be based in part on the technical capability of each system to

perform its intended function. For evaluation of this technical capability, analytical and experimental data must be available to determine the ability of the technique to perform its detection or identification function under anticipated environmental conditions (weather, illumination, trafficability, etc.). For complete evaluation, the technical capability of each system must be viewed in the broader context of the evaluation of the overall military usefulness of the system. This broader evaluation requires a knowledge of the anticipated threat and scenarios for both mine and anti-mine operations. The broader evaluation will be made in terms of a set of military effectiveness criteria covering such factors as casualties, equipment losses, rate of advance, and depth of advance. In addition, other criteria for judging operational usefulness must be assessed, such as life cycle costs, survivability, personnel and logistical requirements, and resistance to enemy countermeasures.

ERIM will participate in the evaluation of military usefulness in cooperation with MERADCOM and BDM, with the system contractor taking primary responsibility for defining the threat, scenario, and operational evaluation criteria to be used for this purpose.

ERIM will also plan the technical program of data acquisition and analysis to take due account of the impact of military usefulness evaluation on selection and definition of technical approaches. This impact will be felt with respect to such factors as terrain and environmental conditions, operational time constraints, area coverage requirements, sensor reliability, survivability of sensor platforms, and so on.

1.4 ORGANIZATION OF THE PLAN DOCUMENT

The remainder of this document presents the plan for work to be performed during the coming year to meet the requirements of the

contract. These plans are presented to cover both technical considerations and management considerations.

In Section 2, a description of the technical work to be performed is given. The discussion includes a rationale for placing high priority on radar and active infrared sensors for further analysis and data acquisition together with the rationale for selecting other promising opportunities for minefield detection systems for further screening and analysis. Work to be done during Plan I on each of the four major tasks is described.

Section 3 contains information of those aspects of the work related to program management. A schedule for performance of the tasks described in the Technical Section is given. Closely related to the scheduling of task effort is the delineation of check points at which specific results should have been achieved and critical decision points at which decisions can be made concerning further directions of major effort. To support the making of critical decisions, major risk areas are delineated. Finally, resource requirements are established wherein personnel, facility, and equipment requirements to support the defined program are given along with plans for making these resources available to the project.

2
TECHNICAL PLAN

2.1 IDENTIFICATION AND SCREENING (TASK I)

The major purpose of Task I is to identify and screen promising techniques for detection of minefields or minelaying operations. This task will result in the selection of those techniques and system concepts which have the best potential for meeting the technical constraints and requirements for the mine detection mission. The selected techniques can be subjected to further analysis, data acquisition, and evaluation during Tasks II, III, and IV. In this section, initial task I efforts leading to Plan I are described, and Task I work scope and a scheme for the organization of Task I efforts is provided.

Schedules, accomplishment milestones, critical decision points and resources needed for accomplishment of Task I are given in Section 3.

2.1.1 INITIAL IDENTIFICATION

In the formulation of Plan I, the opportunities disclosed under the previous contract DAAK70-77-C-0178, together with others presented in the ERIM proposal leading to this contract, have formed the initial basis for screening for technical feasibility. Table 2-1 gives Remote Sensing Recommendations resulting from contract DAAK70-77-C-0178 and Table 2-2 presents a partial list of additional technical opportunities as presented in the ERIM proposal.

A first pass screening of these opportunities has been conducted using initial descriptions of minefield characteristics provided to us by MERADCOM and BDM, together with sensor characteristics and sensor carrier vehicle characteristics available to ERIM.

TABLE 2-1
REMOTE SENSING RECOMMENDATIONS

I. General

1. Obtain classified intelligence data.
2. Use modeling approach.
3. Predict utility.
4. Use multispectral approach.
5. Try special processing.
6. Try pattern recognition.

II. Aerial Photography

1. Improve utility predictions.
2. Make additional reflectivity measurements.
3. Study Landsat data further.
4. Study motion compensation.

III. Thermal Infrared

1. Predict percentage of time useful.
2. Decide on future IR sensor development.
3. Study two-channel silica detection.
4. Study active scanners

IV. Radar

1. Collect dual-frequency, dual-polarization data.
2. Collect spotlight data.
3. Make selected ground measurements.
4. Train radar interpreters on mine warfare.

TABLE 2-2
PARTIAL LIST OF TECHNICAL OPPORTUNITIES

The following list includes techniques to be considered for further effort to the extent that they have not already been incorporated into the Phase I, Task III test program.

Sensor Concepts

- Radar Techniques
 - Millimeter and Submillimeter Wavelength Radar
 - Millimeter and Submillimeter Wavelength Synthetic Aperture Radar
 - MTI Techniques
 - New Developments in METTRA Technology
- Optical Techniques
 - Active Scanner Systems with 3-Dimensional Discrimination Capability
 - Other Optical Techniques Capable of Improved Resolution, Higher Rates of Area Coverage or Smaller Size and Weight
- Acoustic or Seismic Detection of Minelaying Activities
- Indirect Methods of Inferring Mine Location
- Verification of Minefields Through Fuel Air Explosive Weapon
- Detection of Unintentional Radio Frequency Signals
- Transmission Line Detector

Data Processing

- Specialized Data Processing Techniques for Increasing the Reliability or Reducing the Turn-Around Time of Change Detection, Feature Extraction, Pattern Recognition, Position Location, Contrast stretching, ratioing, etc.

Platforms

- Aircraft
- RPV's
- Satellites

TABLE 2-2
PARTIAL LIST OF TECHNICAL OPPORTUNITIES
(Continued)

Platforms (Continued)

- Balloons
- Unattended Ground-Based Sensors
- Ground-Based Vehicles
- Ground-Based Vehicles with Elevated Platforms
- Animals

Methods of Ground Sensor Emplacement

- Aircraft
- Artillery
- Remotely Controlled Ground Vehicles

Near-Real-Time Data Transfer

- Command Control Data Link

2.1.2 APPROACH TO SCREENING

The ERIM approach to the screening process is illustrated in Figure 2-1. Considering a set of minefield characteristics, a set of sensor characteristics and a set of sensor carrier vehicle characteristics, the region of commonality, if it exists, may be considered to represent a region of mutual compatibility where the constraints of all three are satisfied in terms of technical feasibility.

2.1.3 MINEFIELD CHARACTERISTICS

Minefield characteristics include a description of the individual mine and its distinguishing features, the use of the mine in a minefield, the doctrine, tactics and methods of minefield employment, the scenario for its use, the characteristics of the region where it is employed and the various inferential uses associated with it.

This program is concerned chiefly with the anti-tank (AT) and anti-vehicular (AV) mines used by the Soviet Bloc. We have been provided preliminary information regarding these mines together with inert samples of two Soviet mines, the East German PM-60 and the Russian wooden box mine. Four scenarios have been made available to us which are typical examples of doctrine tactics and methods of Soviet use, together with typical time frames and areas involved. The terrain of interest is the West German border areas which are generally exemplified by flat plains to the north and rolling terrain to the south. Some of the basic characteristics of the four scenarios are given in Table 2-3. (For further description of these scenarios, see Appendix A.)

The characteristics of these scenarios may be summarized as follows:

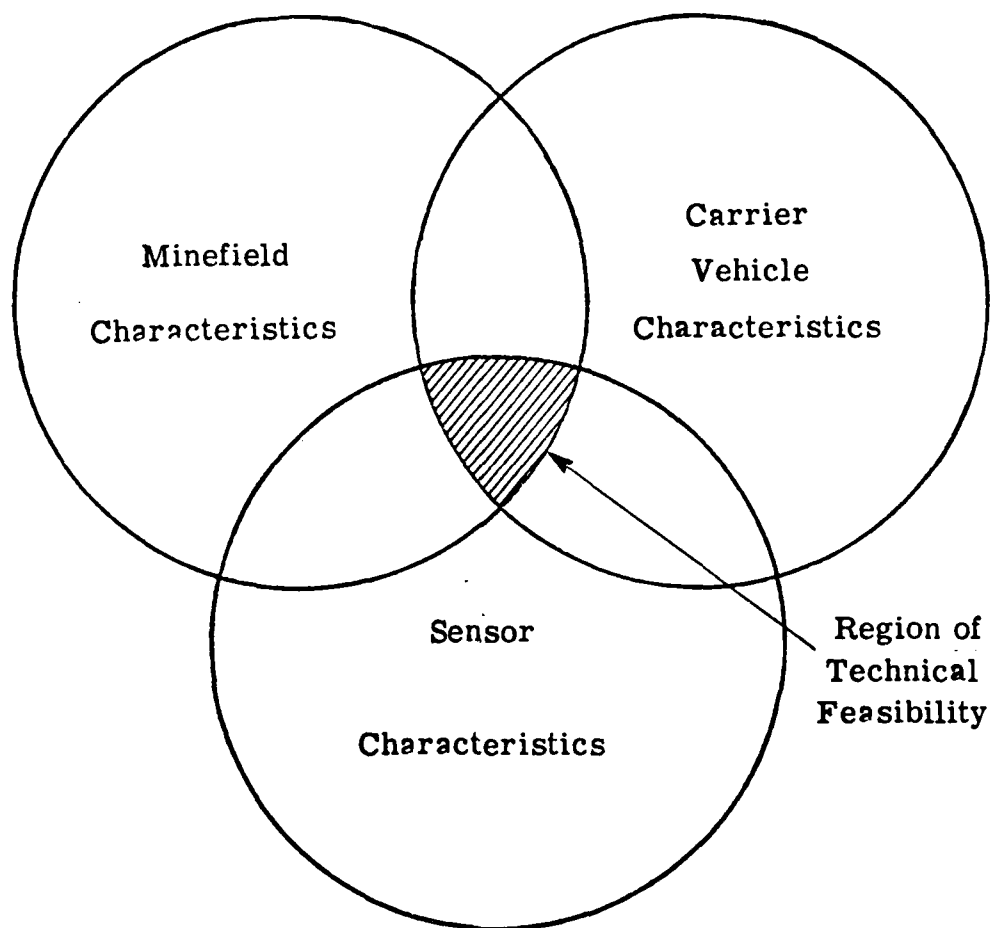


FIGURE 2-1 - CANDIDATE SCREENING PROCESS

TABLE 2-3
FOUR MAJOR SCENARIOS FOR SOVIET MINE WARFARE OPERATIONS

MINE WARFARE MISSION	DOCTRINE AND TACTICS	TYPE OF OPERATION	LENGTH OF TIME MINE FIELD IN PLACE	TYPE OF MINES	NUMBER OF MINES
A. PROTECT MOST EXPOSED FLANK DURING MEETING ENGAGEMENT	<p>(A)</p> <p>OBSTACLE</p> <p>RED</p> <p>BLUE</p> <p>MINEFIELD</p>	OFFENSIVE	1 HOUR	PM 60 SURFACE (Plastic)	545 (50 x 1000 meters area)
B. PROTECT SHOULDERS DURING BREAKTHROUGH (ECONOMY OF FORCE)	<p>(B)</p> <p>FEBA</p> <p>RED</p> <p>BLUE</p>	OFFENSIVE	20 HOURS	TM 46 SURFACE (Metal)	750 (150 x 1000 meters area)
C. BLOCK ENEMY WITHDRAWAL	<p>(C)</p> <p>FEBA</p> <p>RED</p> <p>BLUE</p>	OFFENSIVE	8 HOURS	TM 46 SURFACE (Metal) PM-60 BURIED (Plastic)	60 (50 x 100 meters area) 7 within 50 meter radius
D. SUPPORT PREPARED DEFENSE	<p>(D)</p> <p>FEBA</p> <p>RED</p> <p>BLUE</p>	DEFENSIVE	INDEFINITE	TM 46 (Metal) or MV 5 (Metal)	545 (150 x 100 meters)

- (1) Scenarios A, B, and C are for offensive operations and are characterized as hasty operations with mines being in place a relatively short time. Emplacement and recovery times are significant with respect to in-place times. Scenarios A and B have all their mines surface laid. Scenario C has a great majority of its mines surface laid.
- (2) Scenario D is for defensive operations and is characterized as a deliberate operation with mines expected to be in place a relatively long time. All mines are buried.

2.1.4 TECHNICAL IMPLICATIONS

The technical implications of these scenarios have been developed for use in our initial screening and may be summarized as follows:

- (1) Sensor capability for detection of both surface and buried mines and minefields must be explored.
- (2) To be effective against scenarios A, B, and C, the sensor/carrier vehicle combination must have a quick reaction time.
- (3) Since the Soviet forces have a 24-hour fighting capability and the in-place times for the offensive minefields is relatively short, the sensors should ideally have a capability to operate both day and night.
- (4) An all-weather sensor capability is highly desirable in view of the short in-place times of the offensive mine fields.
- (5) Sensor/carrier vehicle combinations for A, B, and C must be capable of quickly covering areas containing minefields of interest, together with their ancillary operations and installations and transferring information of interest to the local unit commander in a timely fashion so that he may have time to react to the enemy offensive operation.

- (6) The sensor/carrier vehicle combination must not be unduly vulnerable to enemy actions designed to defeat the successful performance of their minefield detection mission. The presence of formidable enemy ground and air defenses associated with these scenarios can be expected. Further, there are significant technical performance restraints imposed on the space/time regime allowed to the sensor/carrier vehicle which can significantly affect its vulnerability.

2.1.5 THE SCREENING MATRIX

Using these technical implications of the scenario as one element and the sensor opportunities presented in Tables 2-1 and 2-2 as another element, a matrix has been constructed (see Table 2-4). This matrix serves to indicate the potential of various technical approaches to satisfy the technical requirements implied by the scenario. Lack of data is indicated by question marks. This matrix has served as one of the bases for selection and prioritization of opportunities for satisfying the mine detection mission. Further, it has served to indicate where current knowledge is insufficient to determine suitability for the mine detection mission.

2.1.6 SENSOR CARRIER VEHICLE CHARACTERISTICS

In addition to the minefield and sensor characteristics, the sensor/carrier vehicle characteristics must be examined for compatibility and availability. The carrier vehicle must be capable of operating in the space/time regime required in order for the sensor to detect minefields and for the system to perform the mine detection mission for the Army. Further, it must be able to accommodate the physical installation of the sensor and provide the necessary power and other ancillary items to support the operation of the sensor.

TABLE 2-4
CHARACTERISTICS OF TECHNICAL OPPORTUNITIES

OPPORTUNITIES	TECHNICAL IMPLICATIONS			REACTION TIME		DAY/NIGHT CAPABILITY	ALL WEATHER	COVERAGE		VULNERABILITY
	SURFACE	BURIED	HASTY	DELIBERATE	WIDE			LIMITED		
Aerial photography (Visual and Near Infrared)	PARTIAL	PARTIAL	?	OK	NO	NO	NO	YES	YES	(MISSION DEPENDENT)
Radar										
Spotlight (ultra high res.)	?	?	?	OK	YES	YES	YES	NO	YES	LOW
X-L (multispectral)	?	?	?	OK	YES	YES	?	YES	YES	LOW
Submillimeter	?	?	?	OK	YES	YES	?	?	YES	?
MTI	NO*	NO*	NO*	OK	YES	YES	YES	YES	YES	?
METRA	PARTIAL	NO***	?	OK	YES	YES	YES	NO	YES	HIGH
Infrared										
Passive	PARTIAL	PARTIAL	?	OK	YES	YES	NO	?	YES	?
Active	?	?	?	OK	YES	YES	YES	?	YES	?
Active 3D	?	?	?	OK	YES	YES	YES	?	YES	?
Other										
Acoustic/Seismic	?	?	?	OK	YES	YES	YES	?	YES	LOW
Inferential Detection	?	?	NO	OK	YES	YES	YES	?	YES	LOW**

*Inferential possibilities only.

**Sensor dependent.

***Unless mine has radiating junction accessible above surface.

2.1.7 PRIORITIZATION, SELECTION, AND INITIAL RECOMMENDATIONS

Based on our initial review of the candidate opportunities listed in Tables 2-1 and 2-2, we observe the following:

- (1) Two of four of our scenarios involve surface mines only. A third scenario has surface mines in preponderance.
- (2) Three of four of our scenarios require quick response.
- (3) Quick response also implies day/night and all weather capability to detect mines.
- (4) Of the opportunities considered in the initial screening, only radar, active infrared, and acoustic/seismic offered potential for meeting day/night and all weather capability.
- (5) The ability of radar and active infrared to detect surface mines (the dominant type in three of four scenarios) is not adequately established.
- (6) The acoustic/seismic approach is not sufficiently well defined at present to allow conclusions regarding its performance.
- (7) The inferential approach depends on sensor capability to detect objects or operations ancillary to a minefield. These capabilities have not been adequately established.
- (8) The ability to detect minefields and provide militarily useful information regarding these on a time scale commensurate with offensive scenarios (hasty Soviet minefields) has not been established.

Considering these observations and using them as a guide in the formulation of our plan, we can categorize the opportunities for minefield detection systems as follows:

- (1) Those for which the next logical step is further exploration and screening to be performed under Task I. These oppor-

tunities include aerial photography and millimeter and sub-millimeter wavelength radar.

- (2) Those for which the next logical step is concept formulation and analysis (Task II). These include acoustic/seismic techniques and inferential detection.
- (3) Those for which the next logical step is the generation or acquisition of field test data which will give a clear indication of the ability to detect minefields (Task III). These include the spotlight radar and active infrared scanner systems.

Aerial Photography

Following the recommendations of the previous contract regarding aerial photography involves an exploration of SCI to ascertain its applicability to the detection of minefields. Upon completion of this exploratory effort, a decision can be made as to whether it is worthwhile to pursue aerial photography further. Accordingly we have incorporated an effort to explore aerial photography and allied SCI as a part of Task I, Plan I.

Radar

Of the radar opportunities listed, ultra-high resolution SAR (i.e., Spotlight radar), multispectral SAR (i.e., the ERIM X-L radar), and submillimeter appear most attractive provided they can detect minefields. Spotlight and X-L in operational configurations could have sufficient range to allow low vulnerability and have the potential for automatic cueing. Both are currently flying in aircraft in configuration which may be suitable for minefield detection and which appear adaptable for operational use. Of these, Spotlight has considerably better resolution and consequently was chosen for incorporation in Task III, Plan I since it appeared to offer the best chance for quickly evaluating radar ability to detect minefields. The millimeter and submillimeter radar is incorporated in Task I, Plan I as a subject for further exploration and screening.

Infrared

Of the electro-optical sensors, the active scanner has several important advantages. The return signal from the target is essentially independent of environmental conditions and, therefore, easier to analyze and interpret. The active feature provides for both day and night operation. High resolution is possible with this scanner at the expense of reduced range and high data rates. Specular reflections obtained from the target are likely to indicate that it is a man-made object; hence, the return may provide some possibility for automatic cueing. The active scanner may also be adapted to measure range to the target and background, thus giving some indication of the target shape in three dimensions. The active scanner planned for measurements as part of Task III, Plan I incorporates both capabilities.

Inferential Detection

Inferential detection is dependent upon the observation of ancillaries to the minefield which are strong indicators of minefield presence. Outputs of the effort being spent in Plan I exploration of sensor capabilities will be considered for suitability for inferential detection of minefields. Thus, data available from aerial photography SCI, radar, infrared efforts and others as appropriate will be explored both for direct and inferential detection of minefields. Accordingly, Task II, Plan I incorporates inferential detection efforts.

Acoustic/Seismic

The acoustic/seismic initial concept has not been formulated sufficiently to allow the necessary operational and technical analysis to be undertaken. However, its potential capability, simplicity and operational adaptability make it appealing. Consequently, it has been included in Task II, Plan I for further concept formulation and analysis.

The characteristics and potential advantages of radar and active infrared systems, which have led to the decision to include them in the Plan I data acquisition program, are discussed further in Section 2.

2.1.8 SUMMARY OF INITIAL TASK I SCREENING ACTIVITIES

- (1) Selection of aerial photography and allied SCI for exploration. (Presented as part of Task I, Plan I)
- (2) Selection of Spotlight radar for testing against a minefield array representative of the scenarios provided by MERADCOM and BDM. (Presented as part of Task III, Plan I)
- (3) Selection of submillimeter radar for exploration. (Presented as part of Task I, Plan I)
- (4) Selection of active infrared scanner for testing against a minefield array representative of the scenarios provided by MERADCOM and BDM. (Presented as part of Task III, Plan I)
- (5) Selection of inferential detection for further concept formulation and analysis. (Presented as part of Task II, Plan I)
- (6) Selection of acoustic/seismic techniques for further concept formulation and analysis. (Presented as part of Task II, Plan I)

2.1.9 IDENTIFICATION OF OTHER CONCEPTS

Under Plan I, sensor/carrier vehicle combinations other than those already selected, will be subjected to the identification and screening process. Potential candidates for consideration include those listed in Table 2-1 and 2-2, based on work performed by ERIM under its previous contract as well as the proposal leading to the present contract. Other possibilities resulting from inputs from

the sponsor, system contractor, the Expert Working Group, literature surveys, and SCI sources will also be considered.

The identification process will be conducted to identify those techniques or equipments which have both technical performance and military operational characteristics suitable for the mine detection application. To be identified as a potential candidate at this early stage, it is necessary to establish only that the technical approach has some prospect of meeting technical and operational requirements and has no obvious deficiencies which clearly restrict its usefulness. During the screening process, these early estimates will be examined further.

The output of this further effort on Task I will be a series of recommendations based on an initial screening of the various techniques and equipments identified for the mine detection mission. In performing the screening operation specified in Par. F.2c(1), consideration will be given to a variety of factors. These include not only the technical performance of each technique, but considerations relating to operational feasibility of the technique as well. Many of these operational considerations ultimately affect the affordability of the system in the military inventory and the utility of the technique under anticipated battle conditions.

In selecting techniques or equipments for further work, consideration will also be given to the advantages and disadvantages of each technical opportunity in comparison with the alternatives being considered. Since the project will not support complete investigation of all the alternatives available, selections must be made keeping in mind available resources for the investigation. Also, selections may be made on the basis of the desirability of various combinations of techniques, so that the final selection will favor techniques that are complementary and avoid duplication of effort on similar approaches.

A complete listing of system concepts to be considered under this task cannot be specified in this plan, but must await the collection and analysis of information from various sources mentioned previously.

2.1.10 CRITICAL DECISION POINTS

Conclusions and recommendations regarding selected technical opportunities will be presented to the second and third meetings of the Expert Working Group. A final revision of the screened opportunities will take into account the recommendations of the EWG and will be used as a basis for making critical decisions regarding further consideration of the individual system concepts.

ERIM will schedule the work in such a manner that it will be able to present at the second EWG meeting in April 1979, its recommendations for reducing a sizable list of possibilities into a relatively small list for more intensive screening. At the third meeting in August 1979, ERIM will present its conclusions and recommendations concerning a final list of candidates considered suitable for further action during the remainder of the program, along with detailed plans for further investigation of these candidates. After revising these plans to take account of critical review and comment by the EWG, these conclusions and recommendations will be included in Plan II to be issued on 5 September 1979.

2.2 SYSTEMS ANALYSIS AND DATA ACQUISITION DEFINITION (TASK II)

In accordance with Par.F.2c(2) and Par.F.2c(3) of the contractual statement of work, this task will be concerned with conducting systems analyses to investigate critical questions governing the usefulness of techniques selected during Task I screening. Where experimental tests or measurements are indicated, these will be conducted under Task III. Task II work will be performed by ERIM to

provide a technical basis for feasibility determinations analogous to the BDM effort to provide a basis for operational feasibility of the candidate mine detection systems.

In order to provide a basis for system analysis and evaluation, suitable criteria will first be adopted for adequate technical and military performance. These will provide a consistent reference for assessing system performance and for comparing and ranking system alternatives. These criteria will be selected jointly by BDM and ERIM with concurrence by the sponsor (Subtask 1). ERIM will also participate in this task by defining conceptual system configurations and characteristics (Subtask 2), and will join with BDM in conducting the preliminary system analysis (Subtask 3).

Systems analyses will be concerned with technical feasibility, performance level, military utility and affordability. Studies of technical feasibility will include definition of sensor and data processing equipment configuration and characteristics, analysis of signature data, modeling of field conditions, and other analytical processes needed to ascertain technical performance with respect to the mine detection process. Operational considerations will include such factors as effect of weather or terrain type and cover on technical performance, suitability of various candidate sensor platforms including survivability of the sensor and sensor platform, number and characteristics of missions needed to cover a given area or a given military engagement, and rough estimates of system and mission costs. It is not intended under Task II to conduct complete and comprehensive systems analyses of the operational features of each technique or equipment, but to be sure that due consideration is given at this point to the implications of performance in a military context.

For many of the techniques, critical information will be needed either for Task II analysis of the concept, or for fuller evaluation

of concept feasibility during Task IV. Where this is the case, one of the primary outputs of Task II will be the identification of critical missing information and the specification of means of filling these information gaps, corresponding to Subtask 5.

Information on technical performance needed for Task II analysis will be acquired through technical consultation, literature survey, or limited laboratory or field experiments. Once the information has been acquired, the concept will be analyzed and either rejected or included in subsequent Task III programs for demonstration testing, using the test array prepared for the purpose as described in this plan.

Since all of the techniques or equipments to be subjected to analysis cannot be firmly established until the screening conducted during Task I has been completed, it is not possible at this time to give precise estimates of the type of analysis or level of effort to be devoted to each technique. Interim results from Task III effort on previously selected candidates will also have some impact on these decisions. Once each system concept has been adequately defined and information requirements determined, a realistic schedule for work on the concept and timing of critical decision points will be chosen.

As the analysis of individual technical opportunities is completed, the results of the analysis will be presented to the Expert Working Group and also to the sponsor for review and approval. Presentation to the sponsor will be made through the preparation of Plan II, due 5 September 1979, accompanied by meetings for reporting project status. Conclusions and recommendations will include both initial assessments of conceptual systems, and where applicable, recommendations for needed data acquisition together with its implementational plan.

2.2.1 INITIAL EFFORTS

Initial Task II effort has been the generation of plans for acquisition of critical data needed in order to further analyze and develop concepts for radar and active infrared mine detection systems. Previous contractual and initial Task I efforts (see par. 2.1.7, items (2) and (4)) have indicated the necessity for acquiring data on their sensory capability against minefields representative of operational scenarios including realistic backgrounds. These plans appear in this document as part of Task III, Plan I.

The initial Task I effort has also indicated that the potential of inferential and acoustic/seismic means for minefield detection is worthy of further concept formulation and analysis. (See par. 2.1.7, items (5) and (6).) Accordingly, Task II, Plan I has these activities included as initial efforts.

2.2.2 ACOUSTIC/SEISMIC SENSORS

Further consideration will be given to seismic and acoustic sensors for the mine detection mission. This study will include not only consideration of the sensors themselves, but of the various methods available which might be used for emplacing them, including airdrops, artillery shells, and remotely controlled ground-based vehicles.

Portions of the U.S. Army program called REMBASS (Remote Battlefield Surveillance System) may be applicable to detecting the laying of minefields. REMBASS type sensory equipment would be keyed to the distinguishing signatures of such an operation. Such signatures could be acoustic or seismic in nature and the sensory equipment could sense either or both of these and use them as a basis for determining and reporting mechanized minelaying operations.

Another method for detecting minefields or mining activity well forward of the FEBA depends on the use of Fuel-Air Explosive (FAE)

weapons. The presence of suspected minefields could be verified by dropping FAE weapons individually on them. If mines were present in the radius of effects of the FAE, the FAE explosions should detonate them. A REMBASS type acoustic or seismic sensor dropped prior to The FAE could be used to transmit signals corresponding to the impulses generated by the explosions.

The initial Task II, Plan I effort will be oriented toward the development of technical performance criteria for the sensors, the associated means for mine detonation (artillery, FAE, etc.) and the means for recognizing that mine detonation has occurred. These technical criteria will be used as a basis for establishing conceptual systems configurations which will then be analyzed for systems capability. If indicated, experimental or other data acquisition programs will be defined. Initial results of the acoustic/seismic Task II effort, together with recommendations, will be reported at the second EWG meeting. It is expected that a decision regarding continuation of this effort will be made after comments are received from the EWG and review by the sponsor.

2.2.3 INFERENCE DETECTION

Inferential detection is the method used to arrive at a conclusion based on the indirect evidence available. In military operations, certain events or actions, generally called indicators, take place that signal the enemy's intention to undertake a particular course of action. One indicator alone does not lead to a conclusion; but, a combination of indicators, in a logical order, makes it feasible for the commander to infer the enemy's possible course or courses of action.

The prudent evaluation and use of indicators for inferential detection has applicability to the detection of remote minefields. Given certain scenario situations, it may be possible to ascertain

the probable locations of minefields through an analysis of the actions the enemy takes prior to or during offense, blocking, or defense operations. Table 2-5 is a list, by no means complete, of some typical indicators and possible areas or items that should be investigated based on different types of operations.

In offense operations, for example, the investigator might be able to determine the possible location of the meeting engagement from a careful study of the terrain; evaluation of intelligence reports; and knowing the enemy's tactics. After selecting candidate locations and studying the enemy's likely courses of action, a determination would be made of areas where the exposed flanks would possibly be located. All candidate locations would have to be monitored or checked on a regular basis so that full attention is not limited to a sole candidate thereby overlooking the others.

Blocking operations pose a difficult problem because these normally occur in the friendly forces' rear areas. The investigator must maintain an awareness of likely areas where a blocking operation could take place. This awareness combined with a knowledge of enemy tactics, terrain and other data unique to blocking operations serve as good tools for inferential detection.

Minefield detection by inference is less difficult to accomplish during defense operations since particular emphasis is placed on their use during this situation. Again, knowledge of enemy defense operations is essential to detection by inference. Particular attention should be paid to the construction of alternate firing positions; erection of obstacles, areas of avoidance on the defender's part, and areas of likely canalization of friendly passes. The intent is to enable the investigator to reach a conclusion using the tools at hand.

Inferential detection is best accomplished when the investigators are well trained in enemy tactics, terrain analysis, and intelligence

TABLE 2-5
INDICATORS OF MINEFIELD LOCATIONS

<u>TYPE OPERATIONS</u>	<u>POSSIBLE INDICATORS</u>	<u>AREAS & ITEMS TO INVESTIGATE</u>
<u>OFFENSE</u>	<p>Concentration of mass in forward assembly areas</p> <p>Clearing and marking of lanes; removal of obstacles</p> <p>Concentration of division-sized units in mass toward the flanks</p> <p>Forward movement of echeloned columns from rear areas</p>	<p>*Main avenues of approach</p> <p>*Assembly areas</p>
<u>BLOCKING</u>	<p>Introduction of airborne of air assault units into enemy rear areas</p>	<p>Critical terrain objectives in friendly rear areas, i.e., road, junctions, bridges, etc.</p>
<u>DEFENSE</u>	<p>Construction and occupation of successive defensive lines</p> <p>Preparation of battalion strongpoints on key terrain</p>	<p>*Obstacles</p> <p>*Battle positions</p> <p>*Areas of likely canalization</p> <p>*Areas of ending avoidance</p>

analysis. It is feasible to use radar imagery collected in the present as well as past programs for studying methods to fully develop inferential detection. For example, the following past programs have application to the task:

<u>Area</u>	<u>Radar</u>	<u>Content</u>
Ft. Benning, GA	Spotlight	Road Junction in Simulated Scenario
Ft. Hood, TX	X-L Band	Military Exercise
W. Germany	UPD-4	Reforger Exercises for 1976 and 1977

A search for applicable imagery should be undertaken so that it may be used in the development of inferential detection methods.

During the inferential analysis, ERIM will list the indicators which would be helpful for the detection of minefields. Then a search will be made for these indicators in applicable imagery from the programs listed above as well as from other sources. An assessment will then be made as to whether radar or electro-optical sensors can detect these indicators. If detection is feasible, what should the resolution and other key parameters be? The output of the analysis will be an assessment of the utility of radar and E-O sensors for minefield detection by inferential means.

As indicated in Par. 2.1.6, data from aerial photography, SCI, radar and infrared will be considered for suitability for inferential detection. Task II efforts in inferential detection will begin when data inputs from these efforts become available. Data inputs from aerial photography SCI are expected prior to the second EWG. An interim report of findings will be presented at this meeting. Spotlight radar and active infrared scanner data outputs will not be available until after the second EWG meeting. Initial findings resulting from these data will be reported at the third EWG meeting, together with further results of the aerial photography explorations.

2.2.4 OTHER OPPORTUNITIES

As other opportunities are defined and screened by Task I activities and found to be attractive candidates for further Task II efforts, they will be phased into the Task II plan. The initiation of Task II effort for other opportunities will be subject to the concurrence of the sponsor.

2.3 ACQUISITION OF CRITICAL DATA (TASK III)

This task covers the acquisition of data needed to answer critical questions governing the usefulness of selected techniques, as covered by Par.F.2c(2) of the contractual statement of work. Task III, as defined here, is intended to cover data acquisition involving sizable efforts which will be implemented after sponsor review and approval. Where it is determined that critical information gaps do not exist for a particular technical opportunity, Task III will be by-passed for that analysis.

The objective of the experiments is to ascertain the capability of the selected sensors to detect and/or identify each of the following features:

- Surface mines
- Buried mines
- Surface minefields
- Buried minefields
- Minelaying equipment
- Minelaying activities
- Ancillary equipment (field fortifications, etc.)

This capability will be determined initially for spotlight radar and active scanner systems, under a variety of environmental conditions, tactical situations, sensor design parameters and operating modes, as listed in the discussion for each type of system.

The criterion for success in evaluating the mine detection and identification capability will be essentially the probability of detection or identification under anticipated battlefield conditions. Laboratory and field measurements and subsequent analysis and modeling will be directed toward interpreting the test data in this manner.

The criterion for success for each element of the test program, itself, is whether it provides sufficient data of acceptable quality to allow decisions to be made regarding sensor ability to detect minefields.

Task III effort in Plan I will begin with the specification and installation of test arrays for collection of critical data on selected techniques. During Plan I, ground or flight tests will be conducted to acquire data on techniques already selected on the basis of previous studies. It will be followed under Plan II by testing of additional equipment and concepts to be selected and analyzed during Plan I.

The definition of data acquisition experiments has been accomplished in the context of the systems analysis process. The technical content and format of the acquired data will be specified so that it is directly adapted to the needs of that process.

The test program has been planned recognizing the operational constraints which must be met by practical systems. The test arrays will simulate essential elements of the various scenarios including various types of terrain likely to be encountered. They will also be designed to accommodate both direct and inferential modes of minefield detection. Selection of sensors and sensor features will be made in accordance with types of surveillance systems presently in inventory or sensor designs which can be reasonably anticipated to perform under battlefield conditions. Ground-based sensors as well as airborne sensors will be accommodated by the test

facilities. It is also recognized that under operational circumstances, detection of minefields may be accomplished as part of a surveillance mission that is directed toward detecting and identifying other types of military targets, as well.

The test plan has been prepared with due consideration for the magnitude of funds available. Although complete tests for a number of variations of environmental, sensor, and system factors would be desirable, the test plan has been designed to give adequate information on the effect of these variables by judicious limitation of the total number of data acquisition flights or experiments. We will take full advantage of procedures which maximize the data acquired within limited costs by such means as using piggy-back flights on other programs and substituting laboratory or ground based measurements for flight testing where practicable.

2.3.1 RADAR SYSTEMS

2.3.1.1 Background

Radar is the only long-range, all-weather sensor available for the detection of remote minefields and minelaying operations. Compared with aerial photography and infrared, much less work has been done on minefield detection with radar; consequently, only a small quantity of radar data dealing with mines and minefields exists. In a previous program, ERIM's X-band measurements on individual mines showed that typical anti-tank mines have low cross sections which makes detection difficult.

Detection of surface mines can occur in two ways. First, if the radar has very fine resolution, the background clutter will be low enough so that individual mines will be visible in the radar maps. A spotlight radar is the only radar which has fine enough resolution for the detection of individual mines. Second, it may be possible to detect the presence of a minefield by an increase in the average

reflectivity of a background. This detection method would be applicable to radars with much poorer resolution than the spotlight radar. Past analysis indicates that the low cross section of mines makes the reflectivity change small and hard to detect unless the minefield is in an area of below-normal reflectivity.

It is even harder to detect a buried mine than a surface mine because of reflections at the air-soil interface and soil attenuation. At X-band, soil attenuation is normally high except in areas of the world where the moisture is exceptionally low. Buried mines may be easier to detect at frequencies below X-band because of lower soil attenuation.

In the first phase of the radar experimental program, minefield arrays will be set up, and data will be collected with ERIM's high resolution spotlight radar. The objective of spotlight measurements will be to study (1) the detection of surface and buried mines as a function of radar resolution and (2) inferential detection methods. Laboratory measurements on mine cross section at L-band will also be made to provide data for detection predictions. After the spotlight and L-band measurement data are analyzed, an assessment will be made of what further radar data are needed. Predictions will be made on radar utility for mine detection at X and L-band, and plans will be formulated for the next phase of the program.

2.3.1.2 Test Arrays

Experimental measurements are required to fill in existing data. Test arrays will be needed for a measurement in the visual and thermal spectral bands as well as at radar frequencies. To minimize costs, the arrays will be located at sites in the Ann Arbor-Willow Run area in Michigan. It is anticipated that there will be sites in two or three different locations. The requirements are as follows:

- (1) The sites should have soil characteristics, moisture content and vegetation representative of Eastern Europe.
- (2) There should be a variety of background including flat land and rolling terrain with vegetation and crops.
- (3) The sites should be representative of tactical situations with surface and buried mines of different types. There should be an opportunity for both direct and inferential detection.
- (4) The sites should be in a location suitable for both airborne and ground-based data collection.
- (5) The mines in the array should either be current Soviet or Warsaw Pact mines or have similar characteristics.

Figure 2-2 is a sketch of a proposed mine array. It is a rectangle 300 m long by 250 m wide, an area which the spotlight radar can cover in a single pass. There are corner reflector clusters at the corners of the array to mark the scene in the radar imagery. The array is divided into 5 strips which are 50 m wide, and the three upper strips are further subdivided into rectangles 100 m long by 50 m wide. Each rectangle contains mines or minelaying equipment. Starting at the upper left-hand corner, the first rectangle will contain a minelayer and a truck with simulated minelaying chutes. In the second rectangle, there will be furrows 100 m long and 15 m apart made by the mine layer, and the top right-hand rectangle will have hand-buried mines laid with a Soviet minelaying cord. The mines will be buried according to standard Army practice*. The three rectangles in the second strip will contain miscellaneous surface mines, metal surface mines in a row pattern (Figure 2-3), and plastic surface mines in a row pattern. The third strip will have dummy mine holes in a strip pattern (Figure 2-4), hand-buried metal mines

*U.S. Army Field Manual, FMS-34, Engineer Field Data.

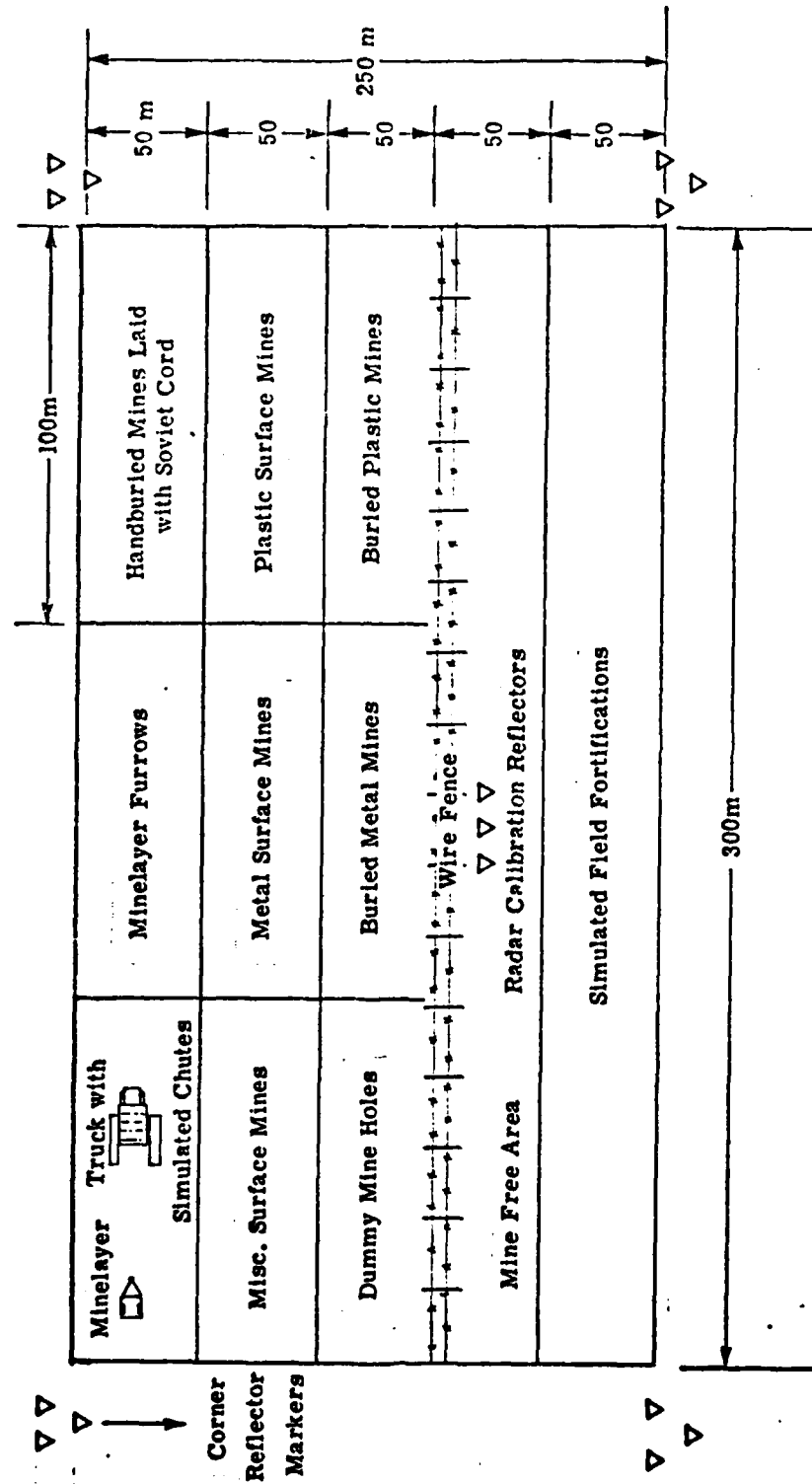


FIGURE 2.2. MINE DETECTION ARRAY

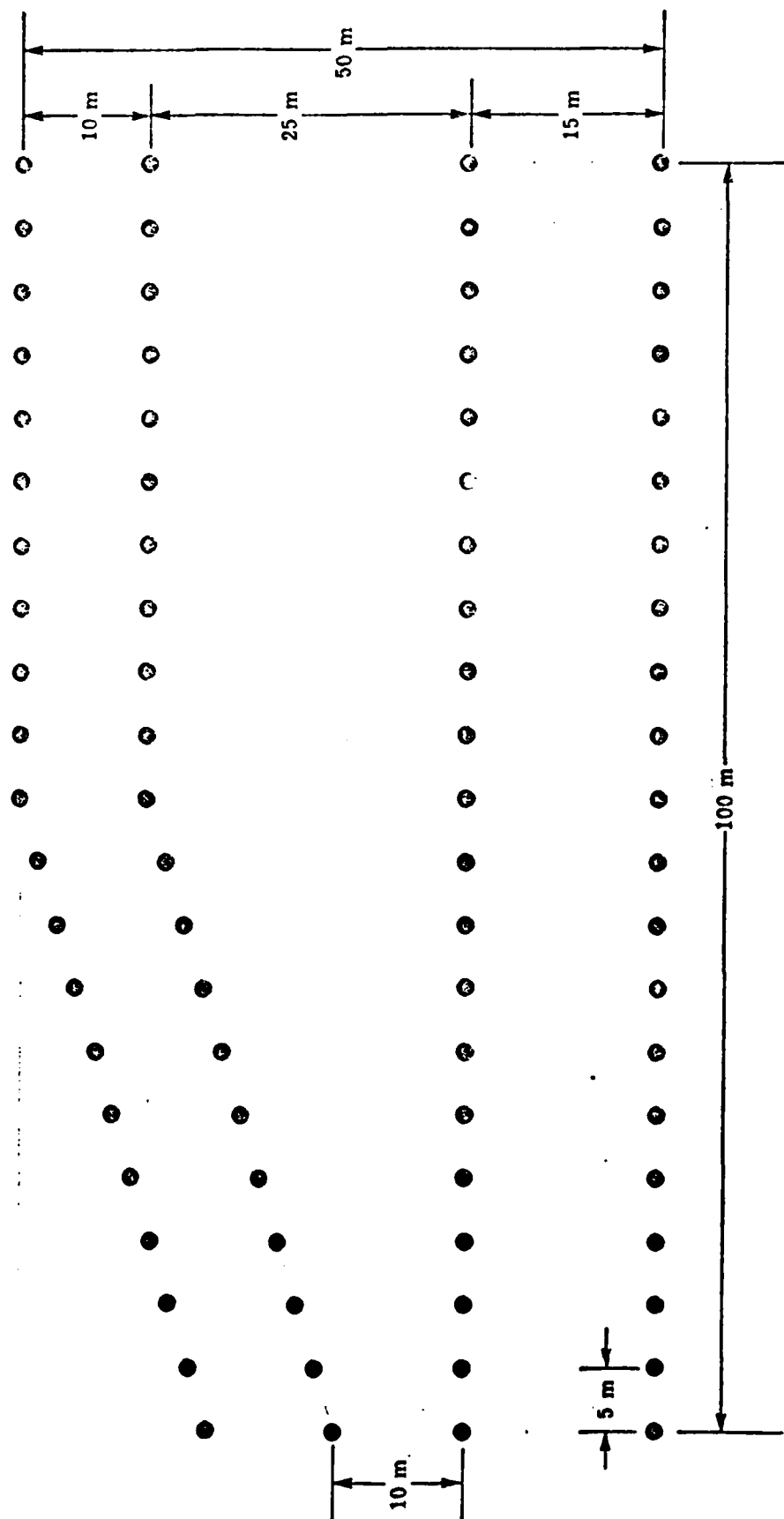


FIGURE 2.3. ROW MINE PATTERN

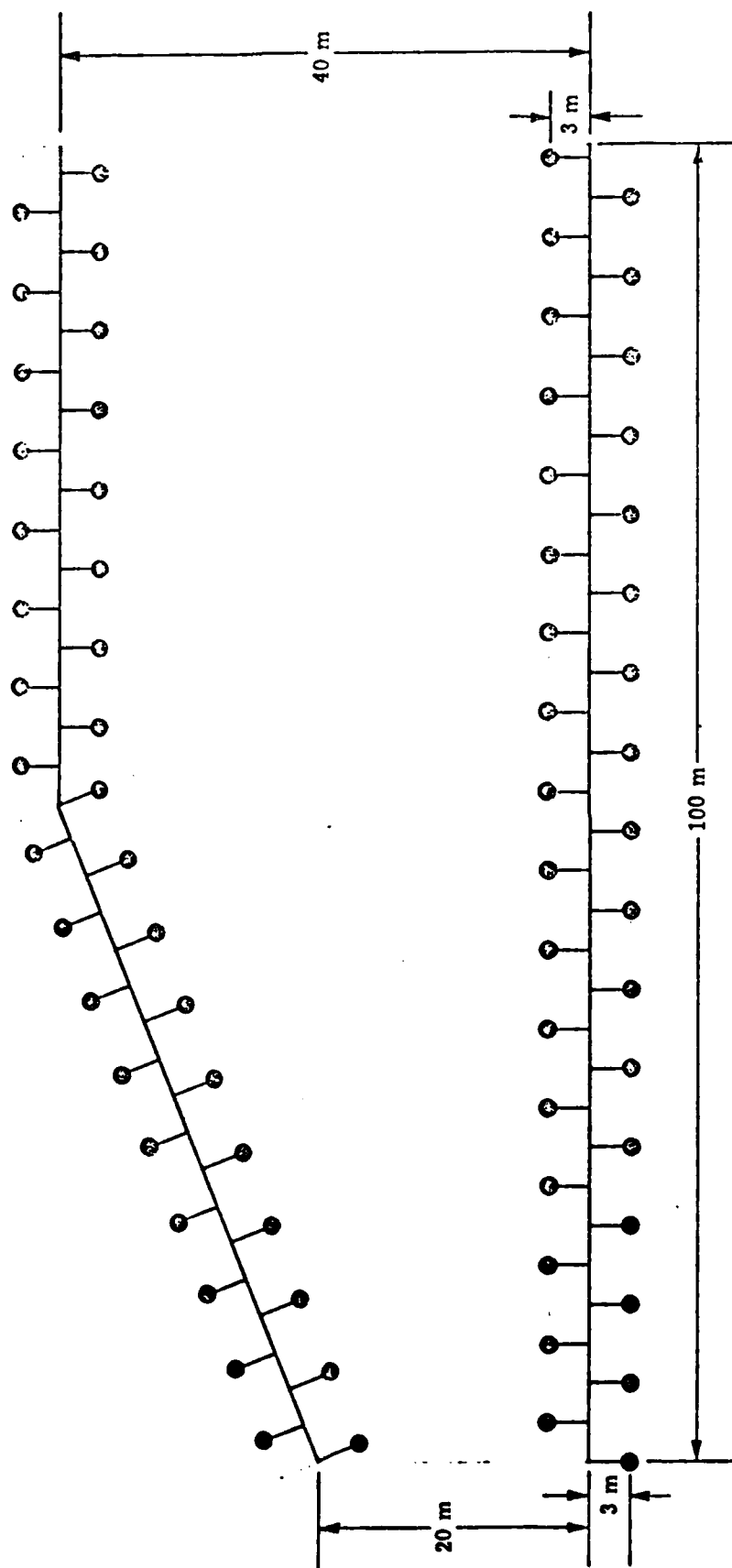


FIGURE 2.4. MINES IN STRIP PATTERN

in a strip pattern, and hand-buried plastic mines in a strip pattern. There will be access paths for vehicles separating the first and second strip and the second and third strip. The spacings in the strip and row patterns are typical for anti-tank minefields.

The fourth strip will be a mine-free control area. The wire fence at the top of the area simulates the fence the Soviets place at the friendly side of their minefields. The corner reflector array in the center of this area is for radar calibration. In the bottom strip, there will be simulated fortifications to provide covering fire for a minefield. Barbed wire will be laid at the front of the strip, and firing positions will be dug behind the wire. Trucks will be driven back and forth in the fifth strip to simulate local traffic patterns.

Each array will require 600 or 700 inert anti-tank mines as GFE equipment. If foreign mines were available, they would be the first choice for the arrays; however, it is unlikely that the Army can provide large numbers of inert foreign mines. It will, therefore, be necessary to use American mines which closely simulate Soviet mines for the majority of the arrays. There should be both metallic mines such as the M-15 and M-21 as well as plastic mines such as the M-19. It would be desirable to place as many foreign mines as possible in the arrays in addition to the American mines. Some mines with tilt rods should be made available for the measurements.

In the previous mine detection program, ERIM measured the cross sections of the M-15, M-19, a Soviet wooden mine (TMD-B), and a simulated plastic East German mine (PM-60). The median cross section of the metallic M-15 was -7 dBsm (dB relative to 1 m^2) and the pattern was symmetrical, while the medium cross sections of the other mines were about -20 dBsm. The PM-60 is symmetrical like the M-15 and it also has a symmetrical pattern, but both the M-19 and the TMD-B are rectangular and the cross section peaks at the normals to the sides.

The M-15 is 13 in. in diameter and 5 in. high compared with a metallic Soviet mine, the TM-57, which is 12 in. in diameter and 4 in. high. The American M-21, which is also metallic, is 9 in. in diameter and 4-1/2 in. high. Since the sizes of the M-15, M-21, and TM-57 are approximately the same, the radar measurement results obtained with either of the American mines should be a reasonably good simulation for the TM-57, either buried or on the surface.

Because the M-19 has approximately the same cross-section pattern and average value as the TMD-B, the results from the M-19 will also apply to the TMD-B when the mines are on the surface. The results should be approximately the same when the mines are buried, because of the similarity in shape and dielectric constant. Since the PM-60 is round and the M-19 is square, the M-19 will not simulate the PM-60 as well.

The test facility will have ancillary instrumentation needed for evaluation of test results, including ground-based sensor equipment, equipment for recording environmental conditions, etc.

2.3.1.3 Spotlight Radar Tests

The spotlight mode of operation differs from conventional synthetic aperture radar strip mapping by providing:

- (1) data collection over a wide angle
- (2) finer resolution
- (3) selected "spot" coverage.

In the spotlight mode, the antenna beam remains fixed on an area on the ground while the aircraft flies past, and the resolution is determined by the coherent processing angle rather than the physical antenna length. Thus, the resolution is no longer restricted to half the physical length of the antennas as is the case with a conventional synthetic aperture radar. The price that is paid for the increased resolution is a restriction on the area coverage.

Although it has been demonstrated that radar can detect minefields under some conditions, there are no data on radar utility for minefield detection in the Eastern European environment. The spotlight radar tests are intended to fill this gap. The spotlight radar is appropriate for radar measurements for two reasons. First, it has the finest radar resolution now obtainable, which maximizes the probability of detecting individual mines, either surface or buried. If individual mines are not detectable with the best resolution possible, they will not be detectable with other radars having poorer resolution. Secondly, since most operational radars now operate at X-band, it is appropriate to collect data with an X-band system.

The technical risk associated with the detection of individual mines is inadequate signal-to-clutter ratio. The average cross section of a metal mine (M-15) on a ground plane is 13 dB higher than that of the nonmetallic mines. Signal-to-noise ratio calculations made in 1977 for the M-15 on the surface indicated that individual mines on the surface should be detectable in most backgrounds with the spotlight radar. Nonmetallic mines, however, should be detectable only in areas where the background reflectivity is low. Some nonmetallic mines are square, and the cross section at the side aspects is high enough so that the spotlight radar can detect them on the surface in most backgrounds.

Since it is possible to degrade the resolution of the spotlight radar by processing only part of the signal history, operational radars with poorer resolution can be simulated with the same raw data that provides the fine resolution. If the mines are detectable, the spotlight radar data will establish radar resolution requirements for detection. Flights with other radars should not be scheduled unless the radars have adequate resolution.

With its fine resolution, the spotlight radar should also be able to detect furrows made by minelayers. Inferential detection by

identifying field fortifications for covering fire, minelayers, traffic patterns, and other clues to minefields will be optimum.

In a pass, the ERIM spotlight radar images a scene 500 m in diameter from a slant range of approximately 5500 m; the depression angles available are 10° , $20-35^{\circ}$, and $40-65^{\circ}$. The polarization can be vertical, horizontal, 45° , as well as circular. The resolution is classified. Although the scene is 500 m in diameter, there are navigation errors of approximately 100 m rms; therefore, the length of the mine array has been restricted to 300 m. There will be approximately 8 passes per flight, enough for two or three passes per site.

After the sites are selected and the mine arrays are installed, flight lines will be laid out for aircraft navigation. There will be calibration reflectors near the center of each array so that absolute cross-section levels can be measured in an optical processor or with digital processing. Drawings will be made of all the arrays showing mine location, type, and whether the mines are buried or on the surface. The drawings will also show the minelayer furrows, the locations of minelaying equipment, and the field fortifications. Photographs will be taken of the arrays, both from the air and on the ground, and weather conditions will be recorded. Measurements will be made of soil characteristics and soil moisture, as required.

It is anticipated that the spotlight data will be collected in late Spring or early Summer. There will be approximately three passes at each of the three sites with a depression angle in the $20-35^{\circ}$ range; different polarizations will be used in the passes. Data will be recorded on digital tape, and processed after the flight. The spotlight ground processing system consists of a digital playback unit, a film recorder and an optical processor; the output signal from the tape playback unit is converted to a polar format and recorded on film for subsequent optical processing. The data

can also be processed digitally at lower data rates and displayed on a cathode-ray tube.

2.3.1.4 Laboratory Measurements

In the previous mine detection program, ERIM made cross-section measurements at X-band of four different mines while the mines were on a ground plane. The data from these measurements was used to calculate the signal-to-clutter ratio for individual mines with a high resolution radar and to calculate the change in background reflectivity for other radars such as the AN/APD-10.

Similar data are needed for L-band modeling to predict the signal-to-clutter ratios and changes in background reflectivity. There is considerable interest in using a frequency below X-band for minefield detection, where there is better soil and foliage penetration. The attenuation of microwave signals varies greatly with frequency, and the attenuation is high at X-band unless the moisture content of the soil is very low. The attenuation is much less at L-band, and the reflected signals from buried mines and from soil disturbances may be higher.

2.3.1.5 Analysis

2.3.1.5.1 Spotlight Data Reduction. The first step in analyzing the spotlight data will be to process images of the arrays with maximum resolution. "Single look" images of each scene will be made from different viewing angles; a "single look" image is an image which is made by processing data over a narrow angular range. Several "single look" images will then be added together noncoherently to form a composite. With this noncoherent integration, speckle is reduced and shape recognition of manmade targets is improved.

The mine arrays will be studied in both the "single look" and composite images. The analyst will determine which are visible and

under what conditions. He will also look for patterns and find whether the furrows, minelaying equipment and field fortifications can be identified. If the mines are detectable with maximum resolution, the data will be reprocessed with coarser resolution so that the analyst can study the degraded imagery and predict what resolution is needed for minefield detection. One possible criterion for determining what resolution is needed is the percentage of mines detected versus radar resolution.

For radar modeling, the analyst needs data on radar cross sections and clutter backgrounds to calculate the probability of detection for a mine or the change in background reflectivity because of the presence of mines. If the individual mines are detectable, measurements of mine cross sections and clutter statistics will be made with ERIM's image dissector facility. The image dissector measures the light intensities of the resolution cells in a target scene; the device is essentially a photomultiplier tube which can be scanned electrically. Light intensity in an image is proportional to radar cross section. Since there will be calibration reflectors in the scene, absolute cross sections can be established. If the signal-to-clutter ratio of the individual mines (or ground disturbances) is high enough, the mine cross sections will be measured and compared with the data ERIM measured in 1977 on the ground. Clutter levels and statistics will also be measured.

2.3.1.5.2 Modeling. There is a need to establish reliable models to describe the scattering mechanism associated with a mine so that the return can be predicted. With a buried mine, there is ambiguity as to whether the mine or alterations of the surface soil volume around the mine causes a detectable signal. There will be three parts to modeling mine scattering. First, experimental data will be collected as discussed above. Secondly, theoretical analyses

will be made of the returns from surface mines, and soil disturbances. Finally, the theoretical predictions will be compared with the experimental results. Some X-band modeling on individual mines were done in the previous program, but there has been no L-band modeling. The goal of this modeling is to predict cross section levels associated with mines or mining disturbances and to determine how the cross section changes with frequency, polarization, aspect angle, and soil composition.

If estimates of the radar cross section are available, the clutter background determines whether or not the mine is detectable. For the detection of individual mines, a signal-to-clutter ratio of about 13 dB is normally required. The average clutter power is equal to the product of the area of a resolution cell and the average background reflectivity (σ_0). The higher the background reflectivity and the larger the resolution cell, the lower the probability of detection. The statistics of the background are also important because they affect the setting of the detection threshold; a spiky distribution requires a higher threshold to keep false alarms down.

Using the mine cross section models, ERIM will make predictions on the minefield detectability at both X- and L-bands. The background data for the predictions will be assembled from data sources already in existence. The predictions will emphasize Eastern Europe and the scenarios expected there. The results will depend on the background, the radar parameters, the type of mine, and whether the mine is buried or on the surface.

2.3.1.6 Summary of Radar Tests

Experimental Variables

Mine type

Surface or buried

Time elapsed since minelaying operation

Mine orientation

Wavelength: X-band (for flight tests); L-band (for laboratory tests)

Resolution: Highest resolution for data collection; degraded values for detection analysis

Polarization

Soil composition, soil moisture content, etc.

Data Collected

Radar cross section

Shape discrimination

Clutter statistics

Ratio of target to background signal.

2.3.2 INFRARED SYSTEMS

Aerial photography (visible or near infrared) with sufficient resolution can detect minelaying operations or surface mines, but the detection of buried mines is more difficult. In the late 50's and early 60's the Army sponsored work on buried mine detection with aerial photography. It was found that detection was good in certain environments, poor in others and impossible in the subarctic.

Imaging systems in the thermal infrared can detect surface mines⁽¹⁾ and it may be possible to detect soil disturbed by a minelaying machine in the thermal band. Under favorable conditions, thermal imaging systems in the 3-5 and 8-12 μm bands can detect temperature anomalies over buried mines. Unfortunately, the temperature anomaly disappears at crossover periods at dawn and dusk, under snow, when the ground is too moist or dry, when there is cloud cover or high winds, or when there are vegetation shadows.

1. Minefield Detection by Airborne Infrared Imaging Techniques, Contract DA-44009-AMC-1200(4), Willow Run Laboratories, University of Michigan, February 1967.

Aerial photography and thermal imaging systems have been studied for some time. Although further work in these areas would be beneficial, one of the intents of the present program is to assess new approaches for minefield detection. A promising area that has not been adequately investigated is the area of high resolution active sensors operating in the near optical and thermal bands at short range (500 to 2000 ft). Such sensors could be deployed in an RPV or a ground vehicle where short range operation is possible. ERIM recommends that the initial E-O data acquisition concentrate on active-system measurements.

2.3.2.1 Active EO Systems

The development of reliable lasers at a variety of wavelengths with adequate power makes active E-O systems feasible, especially for hastily laid surface mines. With active systems, the return is essentially independent of environmental conditions.

The well-documented deficiencies in the passive detection systems for buried mines are also present with surface mines, although they are less severe. The relative contrast (radiance difference) depends on the thermal history. For buried mines that have been in place for some time, one usually has a priori knowledge of the environment (solar isolation, wind conditions, precipitation, etc.) for several days, and detectability predictions may be possible. For hasty minefields, the thermal history of mines coming off trucks and laying on the ground for a short time is unknown. A radiance difference of zero could therefore exist at any time. With active E-O systems, the environmental history is not a factor because the return depends on the reflectivity of the target, not its thermal history. In many situations, a quick reaction is needed, and the capability of the active system to provide data at almost any time is an important advantage over passive infrared systems which are dependent on the past thermal history and the environmental conditions.

A large body of experimental information shows that nature does not produce many specular reflectors, whereas man-made objects have smooth surfaces which are specular at some angles and wavelengths. Active systems detect these specular reflections and the man-made objects from which they originate; this capability often provides a significant advantage over passive systems. Land mines have smooth surfaces which are expected to be specular reflectors. With a large field of surface mines, the probability that a significant number of the mines will have the proper orientation for specular reflection is high. Thus, an active scanning system may be capable of detecting a surface mine field.

The shape of an anti-tank mine and the material it is composed of indicates that specular reflections can be expected at several laser wavelengths. The potential of active E-O systems for the detection of hastily laid surface mines has not been investigated, and measurements of the reflective properties of mines are lacking. Measurements are required to determine if the reflected signals from mines are high enough above the background reflectivity. ERIM proposes to investigate mine reflectivity at $10.6\text{ }\mu\text{m}$ (CO_2 laser) where past studies have shown that man-made objects produce good specular returns. Both reflectivity and contrast will be investigated at $1.06\text{ }\mu\text{m}$ (Nd laser). The lasers at these wavelengths are reliable, and output powers of 20 to 50 watts are available without special modifications.

An active system in an RPV at a 1000 ft altitude or in a ground vehicle can operate 24 hours a day in almost all weather conditions except rain and heavy fog. Although an active system is more complicated than a passive system because it carries its own source, signal processing may be simpler because of the cueing provided by the specularity of the returns.

2.3.2.2 Experimental Measurements and Analysis at 10.6 and 1.06 μm

The experimental measurements will be carried out at the Willow Run Airport at ERIM's E-O measurement range. This range consists of an instrument bay 80 ft above ground level which views a test site 800 ft long (see Figure 2-5). The objective of the measurements is to obtain calibrated reflectivity data from surface and buried mines under carefully controlled conditions. The ground measurements will provide data to assess detection feasibility at less expense than an airborne data collection program.

For the mine measurements, an existing AVD-4 scanner will be modified to incorporate a 10.6 μm source in addition to the 1.06 μm source already in the system. The mines will be located in the test area as sketched in Figure 2-6 and will be scanned at 10.6 and 1.06 μm ; beam spot sizes will be approximately 0.2 and 0.5 ft. During the measurements, the mine orientations will be changed to provide data on reflectivity as a function of aspect angle. Four sample mines of each class will be measured to indicate target variability. The mines used will include the Soviet TMD-B and East German PM-60 now at ERIM as well as other Soviet and Warsaw Pact mines which the Army can provide. US mines and other analogs will be employed as substitutes for Soviet mines which are unavailable. Although surface mines will be emphasized, buried mines will also be scanned. If possible, data will be collected during both winter and spring. These are the two seasons which have the highest populations of natural specular reflections in the background.

Although the processing and analysis of the active data will start as the data are collected, the analysis will not be completed until after Phase II of the program has started. Only a preliminary assessment of active sensor utility will be possible before the plans for Phase II are formulated; final conclusions about the potential utility of E-O will be available by December 1, 1979.

To Be Used To Make 1.06 Micrometer, 10.6 Micrometer
And Range Measurements

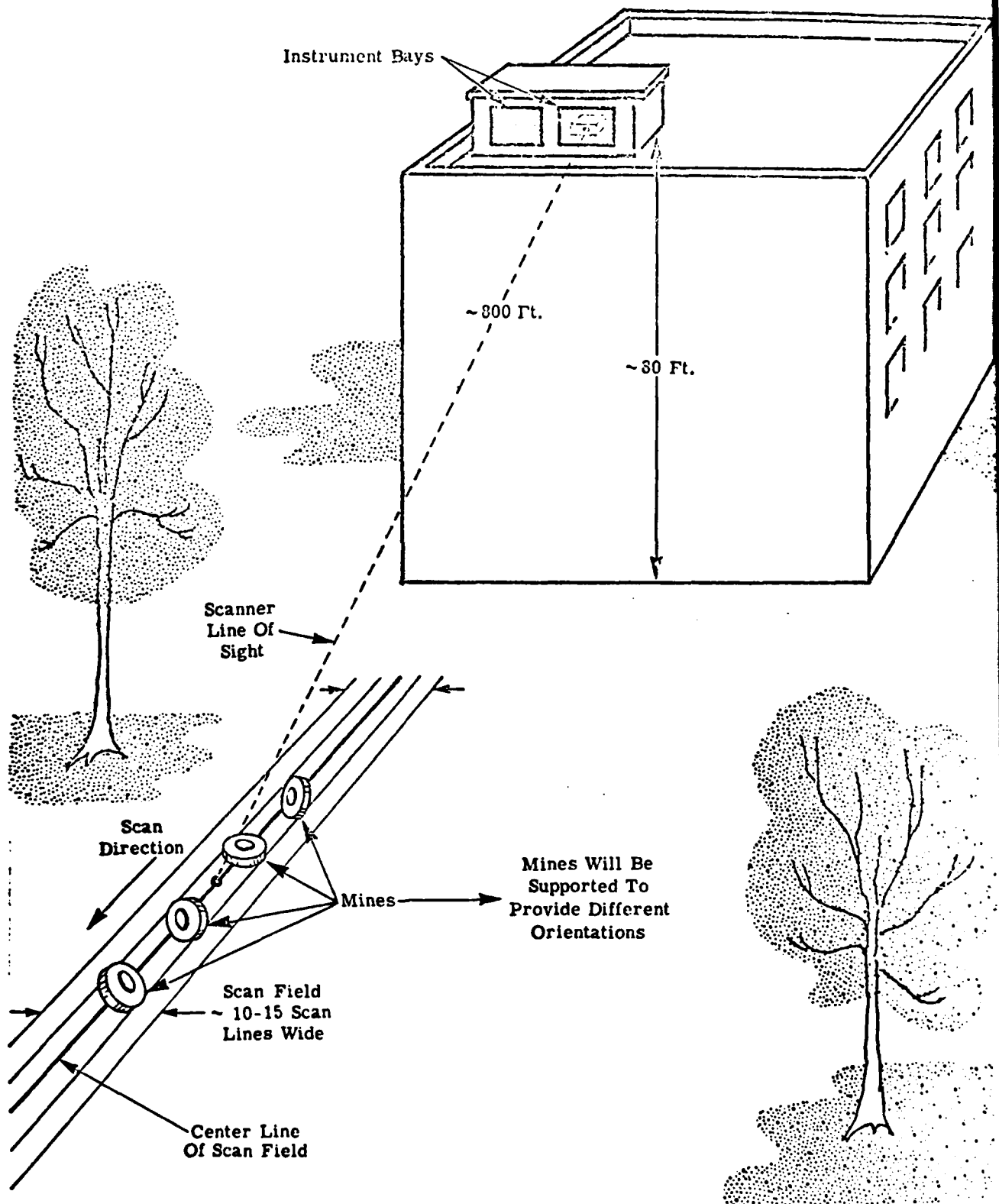


FIGURE 2.5. ROOF TOP INSTRUMENT FACILITY

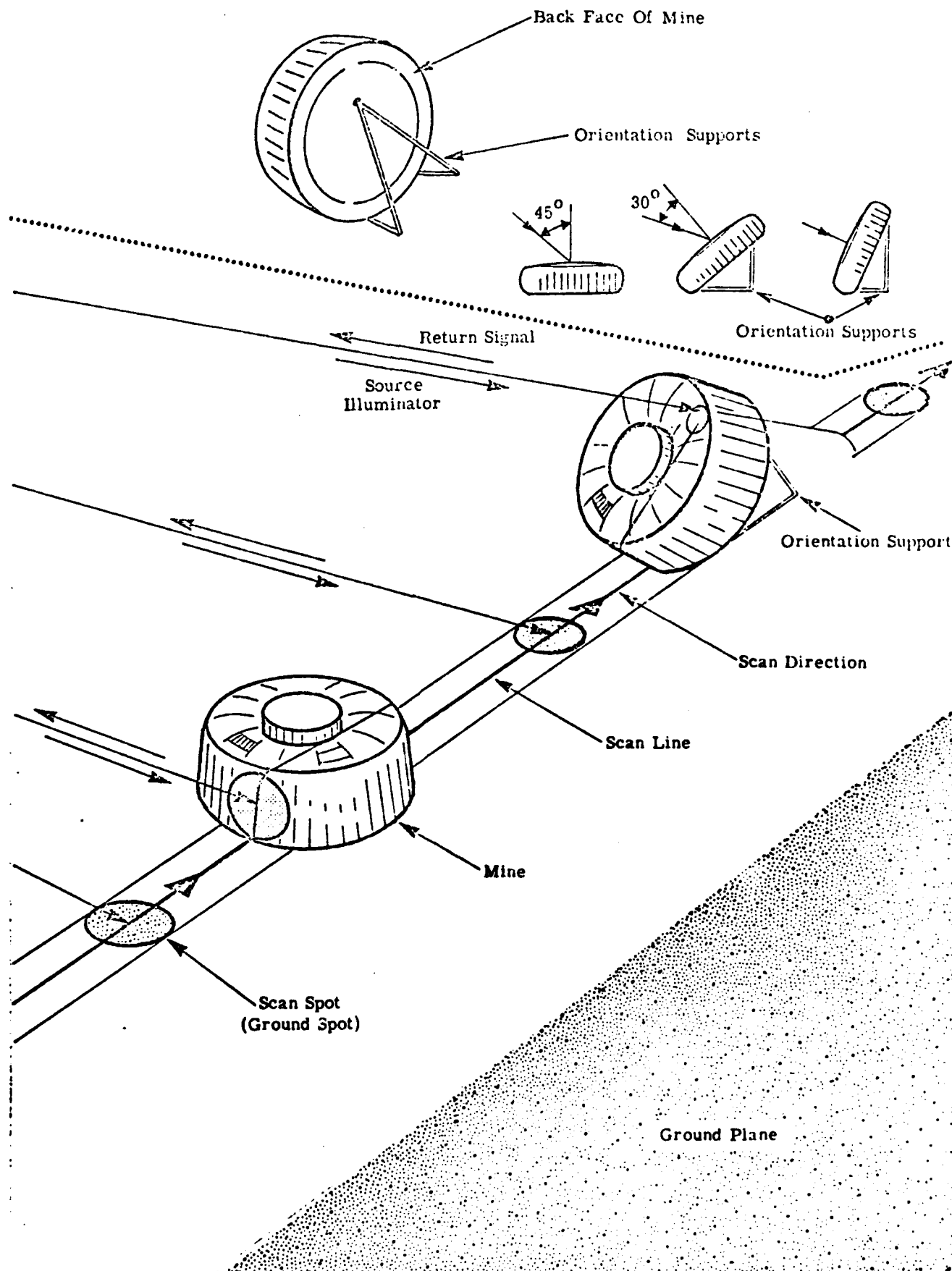


FIGURE 2.6. MINE AND SCAN LINE GEOMETRY

For the analysis, scans will be processed to provide images which can be studied to see if mines are detectable. In addition, single scans from surface mines will be analyzed to find mine reflectivity at 10.6 and 1.06 μm and mine contrast at 1.06 μm . The statistics of the background reflectivity to background reflectivity and false alarm rate.

2.3.2.3 Modulated Active Systems (3-D Systems)

In addition to the conventional active systems described above, the modulated active system developed by ERIM has considerable potential. The system, which uses a modulated 1.06 μm laser generates imagery with range information to every point in the scene⁽²⁾. The imagery is three-dimensional with x, y, and z coordinates for every point in the scene. The data can be processed with three-dimensional spatial processing algorithms that are much more robust than the more familiar two-dimensional algorithms applied to conventional imagery.

3-D range data will be collected for the same targets and geometries as the conventional 10.6 and 1.06 μm active scanners. The 3-D data will be processed to form images, and the images will be studied to determine whether mines are detectable. Previous experience with the 3-D data indicates that the mines should stand out as well defined returns in contrast to diffuse returns from natural backgrounds.

2. M. Bair, et al., Investigation of Active/Passive Line Scan Techniques, Report No. AFAL-TR-75-162, ERIM, Box 8618, Ann Arbor, MI, Jan. 1976 (CONFIDENTIAL/NOFORN).



2.3.2.4 Summary of Active Scanner Tests

Experimental Variables

Mine type
Surface or buried
Time elapsed since minelaying operation
Mine orientation
Wavelength: 10.6 μm (reflectance), 1.06 μm (reflectance and range information)
Resolution: Spot sizes of 0.2 ft and 0.5 ft
Background
Season of year
Existence of haze, precipitation, etc.

Data Collected

- 1) Active sources at 10.6 and 1.06 μm
Imagery of surface and buried mines
Reflectance data
Statistics of backgrounds
- 2) 3-D modulated sensor
Images with range contours.

2.3.3 RESULTS OF THE ANALYSIS AND FUTURE PLANS

The analysis of the radar data will influence the plans for the second year's effort. Several alternative conclusions are possible with regard to the detection capability of radar as well as other possible sensors. Possible conclusions are:

- 1) Individual mines are detectable under some conditions.
- 2) Individual mines are not detectable, but minefields are detectable under some circumstances.
- 3) Detection is possible only by inferential means.



- 4) Detection of either individual mines or minefields, directly is impossible.
- 5) More information is needed to reach a judgment on the sensor's utility.

The spotlight radar data will furnish information on individual mines, minefields, and inferential detection. Second year flights with the ERIM X-L radar can provide additional information of a complementary nature. With this radar, four channels of data can be recorded per pass as opposed to a single channel for a conventional SAR. Thus, dual-frequency and dual-polarization data will be available for detection investigations. A judgment on collecting X-L data will be made after the spotlight data are analyzed.

Another possibility is the use of millimeter or submillimeter-wave radar. At these frequencies, components are small in size and lightweight systems could be built for short range operation from RPV's. Real aperture as well as synthetic aperture systems should be considered. For modeling, millimeter or submillimeter-wave measurements of mine cross sections in the frequency bands of interest are needed. As at lower frequencies, calculations of signal-to-clutter ratios are needed for detection predictions in various backgrounds. If minefield detection is possible at X-band, it should also be possible at higher frequencies.

MTI radar is a possibility for inferential detection if sufficient time is available for traffic patterns to be observed. The absence of traffic in an area along with other information may indicate the presence of minefields. Inferential detection with MTI radar will be most useful for defensive minefields, not hastily laid minefields where a quick response is required.

Developments in METTRA systems should be monitored. METTRA systems might find application in ground vehicles, where the short



operating range would not be as great a disadvantage as in an airborne system. For a thorough analysis, data will be needed on the harmonic cross section of typical Soviet and Warsaw pact mines, both metallic and non-metallic.

The active E-O sensors require either adequate contrast between the mine (either buried or on the surface) and the background or glints off the mine surface for mine detection. Although the active measurements of these properties will be completed by the summer of 1979, only a preliminary look will be available while plans for Phase II are formulated. The processing and analysis of the active data will continue during Phase II until 1 December 1979. Recommendations on further work in the area will be available for EWG 4. If an active scanner shows promise in either or both of the bands, 1.06 or 10.6 microns, or with three dimensional capability, additional analysis and measurements from an airborne platform or on the ground can be scheduled. The airborne measurements would be conducted over the test arrays set up for the radar measurements.

After inputs in the visible, near infrared, and thermal infrared bands are obtained from SCI sources, recommendations will be made on future work in these areas. It may be desirable to collect data with a multispectral scanner either from the air in conjunction with an active source or from the ground.

Acoustic or seismic sensors might be useful for detecting mines detonated by artillery shells or other devices. Some tests would be appropriate to determine if two explosions very close together in time can be detected. Acoustic or seismic sensors might also be able to detect minelayers and/or minelaying activities. There are a number of other technical opportunities listed in Section 2.1.2 and new opportunities not yet uncovered which warrant investigation.

Inferential detection is possible with various sensors and combinations of sensors, and investigations on inferential methods will continue during the second year.

Special processing techniques should be considered for radar, aerial photography, electro-optical and other sensors which have appeared to have good enough performance. For example, mines are usually laid in patterns which do not occur in nature. Pattern recognition techniques would be appropriate for sensors whose resolution is good enough to resolve individual mines so that a pattern might be distinguishable. Pattern recognition techniques are not appropriate for sensors like the AN/APS-94 which cannot resolve individual mines.

Ratioing and contrast stretching should be applied as appropriate data become available. Contrast stretching should be applied to spotlight data, to any X-L radar data collected or active and passive scanner data collected in the second year.

2.4 SYSTEM EVALUATION AND RECOMMENDATION

This task represents the completion of the systems analysis effort initiated under Task II. Additional detailed analyses will be possible based on the data acquired during Task III.

The performance of overall systems analysis and evaluation is the primary responsibility of the system contractor. ERIM will support the system contractor in performing this function by providing and interpreting Task III test results, refining technical criteria for system evaluation based on experience gained during the program and assisting in the evaluation of technical performance, military usefulness, and affordability of the system considered.

The approach to this evaluation is illustrated in Figure 2-7. Data acquired through experimental measurements, literature survey, access to SCI, etc., are used to define a region of technical feasibility for candidate opportunities, indicating those system concepts which meet the technical requirements for mine detection. Technical

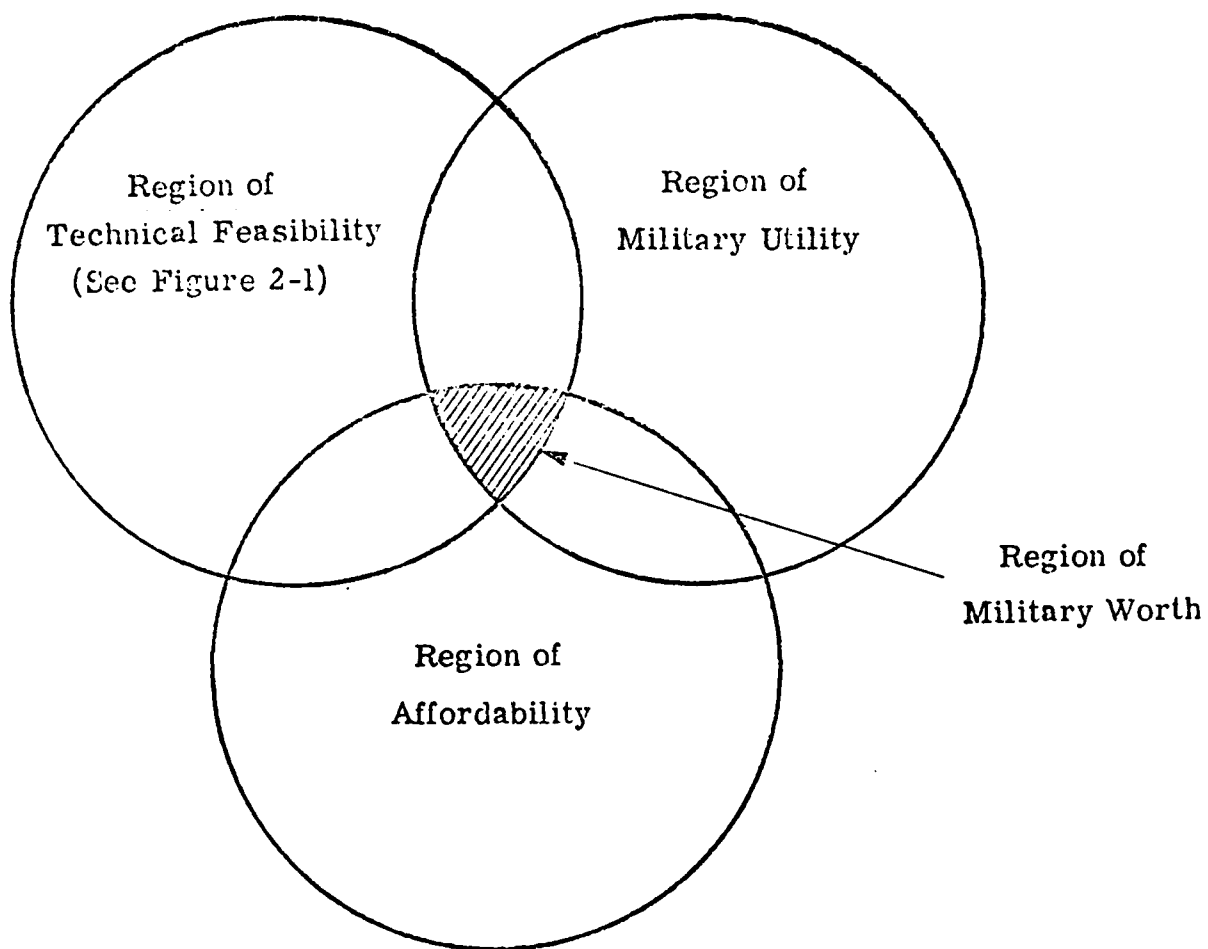


FIGURE 2-7 - MILITARY EVALUATION PROCESS

feasibility is determined by using the procedures shown in Figure 2-1. In addition to technical feasibility, recommended systems must fall within a region of military utility and affordability. System concepts which meet all three requirements fall in a region of military worth and will be recommended for further consideration and development effort.

The output of this task will thus include an evaluation of each technical opportunity with respect to technical performance, military usefulness and affordability. If a full evaluation is not possible, uncertainties requiring study beyond the scope of this contract will be identified, as called for in Par. F.2c(3). To the extent possible, recommendations will be made for further development of preferred systems or combinations of systems. Depending on the present status of military research and development programs or operational hardware components, these recommendations may call for additional programs at various stages of Army development or procurement.

The analyses and evaluations performed during the contract are intended to consider only the major operational aspects of the application sufficient for the appropriate level of decision-making by the sponsor. They may also serve as a basis for more detailed analyses and evaluations to be conducted in subsequent contractual efforts.

Based on the results and conclusions obtained from project performance, ERIM will develop Project Plan III for recommended future action or minefield detection programs, and will also prepare and submit a final technical report. Final results of the project will be reviewed by the EWG and by the sponsor for comment and approval before final submission.

Since the major part of this work will be performed during a later phase of this project, detailed plans for performing Task IV work will be presented during Plan II.

3
MANAGEMENT PLAN

In Section 2 of this document, a detailed work description has been presented for accomplishing mine detection program objectives during Plan I, extending from 1 January 1979 to 5 September 1979, at which time Plan II will be submitted to the sponsor for review and approval. Section 3 describes a management plan designed to delineate the organization and scheduling of the effort. Management visibility of the project is also provided by the presentation of accomplishment milestones, critical decision points and an assessment of technical risk involved. Resources needed for program accomplishment are delineated together with plans to provide them. Resource plans are provided for the necessary personnel, facilities, equipment, materials, and services needed to accomplish the project effort as scheduled.

Section 3 first outlines the task structure which organizes the work to be performed under the project into tasks and subtasks (Section 3.1). Following this, time schedules for performance of the individual tasks and subtasks during Plan I are presented, including important accomplishment milestones and critical decision points together with an assessment of technical risk involved (Section 3.2). The work program, as summarized in the schedule and accompanying discussion, is then used as a basis for a resource plan, showing personnel, facilities, equipment, materials, and services required to accomplish the planned work (Section 3.3).

3.1 ORGANIZATION OF MINE DETECTION EFFORT

The organization of the mine detection effort into tasks and subtasks to be performed under this project is outlined in Table 3-1. The

TABLE 3-1. ORGANIZATION OF MINE DETECTION EFFORT

TASK I. IDENTIFY AND SCREEN PROMISING TECHNIQUES FOR MINEFIELD DETECTION

1. Establish EWG (complete prior to initiation of Plan I). ✓
2. Establish contacts within intelligence community ✓
 - (a) Initial contacts including plan for further contacts
 - (b) Further contacts
 - (1) Establish contacts as needed for overall task performance
 - (2) Assess information gained through further contacts
 - (3) Assemble information in form useful for overall task performance
3. Provide technical support to systems analysis contractor in identifying useful remote detection techniques and equipment ✓
 - (a) Based on intelligence community contacts and other mine/minefield characteristics and use available to the contractor, develop remote detection technical requirements. (Includes aerial photography.)
 - (b) Survey remote detection sensory technology for potential to meet these requirements.
 - (1) Identify reconnaissance systems now in inventory which may be effective against minefields.
 - (2) Identify systems now in inventory which may be made effective against minefields by means of unconventional employment or minor hardware changes.
 - (3) Identify new techniques which may be developed specifically for mine detection.

4. Provide technical support to systems analysis contractor ✓
in identifying other methods for detecting minefields or
mining activity well forward of the FEBA.
 - (a) Based on intelligence community contact and other
mine/minefield characteristics and use available
to the contractor develop detection technical
requirements for other methods for detecting mine-
fields or mining activity well forward of FEBA.
 - (b) Survey detection sensory technology for potential
to meet these requirements.
5. Provide technical support to systems analysis contractor ✓
in screening most promising techniques.
 - (a) Develop technical criteria for initial screening.
 - (1) Mine/minefield characteristics
 - (2) Sensory capability
6. Conduct EWG meeting 2. ✓
7. Prepare CY1978 reports and recommended Project Plan 1. ✓

TASK II. PROVIDE TECHNICAL SUPPORT TO PRELIMINARY SYSTEMS ANALYSIS OF CANDIDATE SYSTEMS AND DEFINE EXPERIMENTAL OR OTHER DATA ACQUISITION PROGRAMS

1. Assist systems analysis contractor in the selection of preliminary technical performance criteria, based on expansion of criteria developed for initial screening until appropriate for systems analysis of selected techniques. FY80
 - (a) Mine/minefield characteristics
 - (b) Sensory capability
 - (c) Other
2. Using technical performance and military criteria developed by the systems analysis contractor as a basis, define conceptual systems and develop conceptual systems configurations exploiting mine/minefield distinguishing characteristics for the techniques selected in Task 1. FY80
 - (a) Sensor system variations
 - (b) Data processing systems variations
 - (c) Sensor platform system variations, if applicable
 - (d) Variations in operational use
3. Provide technical support to systems analysis contractor in the conduct of a preliminary systems analysis. FY80
 - (a) Analyze system capability in terms of technical performance.
4. Deleted
5. Define experimental or other data acquisition programs. FY-80
 - (a) Experimental program
 - (1) Objectives of program
 - (2) Criteria for success

- (3) Experimental procedure
- (4) Site specification
- (5) Equipment required
- (6) Other
- (b) Data acquisition program
 - (1) Objectives
 - (2) Criteria for success
 - (3) Methodology
 - (4) Other
- 6. Conduct EWG meeting 3.
- 7. Prepare reports January through August 1979 and recommended Project Plan II.

TASK III. ACQUIRE CRITICAL DATA

1. Conduct critical experiments
 - (a) Implement test sites
 - (b) Conduct experiments defined in Task II.5(a) and recommended by EWG
 - (c) Conduct experiments identified or defined under Contract DAAK70-77-C-0178 and reviewed and recommended by EWG
 - (1) Aerial photography
 - a. Reflectivity measurements using multispectral scanner
 - (2) Active Infrared Scanner
 - a. Flight tests to ascertain ability to detect mines
 - (3) Radar
 - a. Collect dual frequency, dual polarization data
 - b. Collect spotlight data
 - c. Make selected ground measurements
2. Assemble information from external sources
 - (a) Data acquisition programs defined in Task II.5(b) and recommended by EWG
 - (b) Data acquisition programs identified or defined under Contract DAAK70-77-C-0178 and reviewed and recommended to EWG
 - (1) Aerial photography
 - a. Acquire data regarding weather limitations
 - b. Acquire information regarding utility of Satellite data
 - c. Acquire information regarding problems in motion compensation

- (2) Thermal infrared
 - a. Acquire data on percent of time useful
 - b. Acquire additional data on silica detection
 - c. Acquire data on IR reflectance of loose and packed soil
- 3. Acquire relevant SCI (Refer to Task I.2).
- 4. Adapt critical data to systems analysis format.
 - (a) Relate data to systems analysis format
 - (b) Determine data confidence level
- 5. Conduct EWG meeting 4.
- 6. Prepare reports September 1979 through June 1980.

TASK IV. PROVIDE TECHNICAL ASSISTANCE TO THE SYSTEMS ANALYSIS CONTRACTOR IN EVALUATION OF CONCEPTUAL SYSTEMS FOR TECHNICAL AND MILITARY USEFULNESS

1. Assist systems analysis contractor by translating Task III outputs into forms suitable for systems analysis.
2. Support systems analysis contractor in reassessment and expansion of technical criteria.
 - (a) Mine/minefield characteristics
 - (b) Sensory capability
 - (c) Operational system and military usefulness considerations
3. Support systems analysis contractor in evaluation based on revised criteria.
 - (a) Technical status
 - (b) Military utility
 - (c) Cost and other affordability aspects
 - (d) Assessment of program risks
 - (e) Time frame involved
 - (f) Other criteria
4. Conduct EWG meeting 5
5. Prepare reports July 1980 through November 1980 and final technical report together with Project Plan III for future action.

The work is to be performed under four major tasks:

- Task I - Identification and Screening
- Task II - Preliminary Systems and Analysis
- Task III - Critical Data Acquisition
- Task IV - Evaluation of Technical and Military Usefulness

Detailed discussions of the technical effort to be performed under each of these tasks during Plan I have been presented in Section 2. In the following sections of the management plan, schedules, resource requirements, etc. are keyed to the individual tasks and subtasks of the task structure in Table 3-1.

3.2 TIME SCHEDULE

Figure 3-1 shows the overall schedule for the mine detection project. Scheduling of five Expert Working Group meetings and submission dates for three Project Plans are shown. Fitting into this overall schedule is a detailed schedule, shown in Figure 3-2, for the work to be accomplished under Plan I. This schedule has been prepared to allow compatibility between the accomplishment of major milestones and the time frame in which critical decisions must be made. During Plan I, the schedules will result in providing information needed at the second and third meetings of the Expert Working Group, and providing timely inputs for the preparation of Plan II.

From the schedule of Figure 3-2, a listing of milestones and critical decision points has been prepared (Table 3-2).

3.3 CRITICAL DECISION POINTS

Plan I will result in the acquisition and analysis of information which will permit the making of specific critical decisions on the type and extent of further effort to be devoted to each of the techniques investigated. The time at which each of these critical decisions

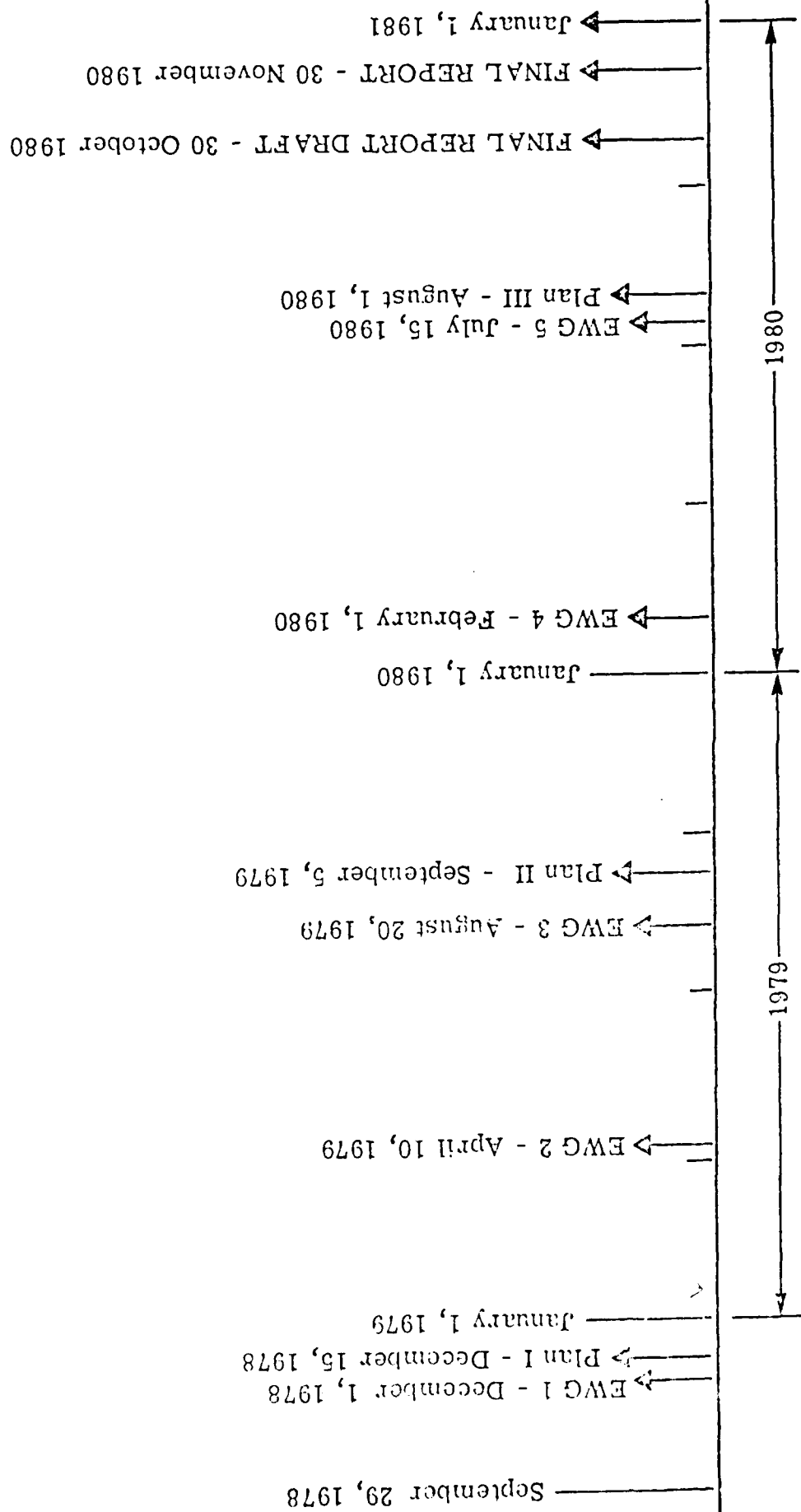


FIGURE 3.1. PROJECT SCHEDULE OVERVIEW

FIGURE 3.2

PROGRAM SCHEDULE

PROGRAM Detection of Remote Minefields TASK I - Identification & Screening REV. DATE

ITEM	1979												1980												REMARKS:	SHEET 1 OF 2		
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			25	26
1. Establish EAG	Completed																											
2. Contacts with intelligence community	✓	1					✓	2					✓	3				✓	4									
Aerial photography (see Sec. 2.1.7)																												
3. Identify remote detection techniques																												
4. Identify other techniques																												
5. Screen promising techniques																												
Millimeter and submillimeter radar (see Sec. 2.1.7)																												

REMARKS:

KEY: XXXX Forecast Event

TABLE 3-2
ACCOMPLISHMENT MILESTONES - TASK I

SUBTASK	MILE- STONE	DATE	DESCRIPTION
2. SCI contacts	M1	Mar. 15, 1979	Summarization of initial SCI contacts and resultant recommendations prior to EWG2
	M2	July 15, 1979	Summarization of further SCI contacts and resultant recommendations prior to EWG3 and Plan II
	M3	Jan. 15, 1980	Summarization of further SCI contacts and resultant recommendations prior to EWG4
	M4	July 1, 1980	Summarization of SCI contacts and resultant recommendations prior to EWG5 and Plan III
	M5	July 1, 1979	Summarization of exploratory contacts to investigate suitability of aerial photography for minefield detection together with recommendations and bases for decision (see critical decision 1)
3. Remote identification	M6	Mar. 1, 1979	Summarization of further efforts to identify remote techniques for minefield detection together with recommendations prior to EWG2
	M7	July 1, 1979	Summarization of further efforts to identify remote techniques for minefield detection together with recommendations prior to EWG3
	M8	Jan. 1, 1980	Summarization of further efforts to identify remote techniques for minefield detection together with recommendations prior to EWG4

ACCOMPLISHMENT MILESTONES - TASK I
(Continued)

SUBTASK	MILE- STONE	DATE	DESCRIPTION
4. Identification (Other)	M9	Mar. 1, 1979	Summarization of further efforts to identify other suitable techniques for minefield detection together with recommendations prior to EWG2
	M10	July 1, 1979	Summarization of further effort, to identify other suitable techniques for minefield detection together with recommendations prior to EWG3
	M11	Jan. 1, 1980	Summarization of further efforts to identify other suitable techniques for minefield detection together with recommendations prior to EWG4
5.	M12	May 1, 1979	Summarization of further efforts to screen techniques for minefield detection together with recommendations prior to EWG2
	M13	July 1, 1979	Summarization of further efforts to screen techniques for minefield detection together with recommendations prior to EWG3
	M14	Jan. 1, 1980	Summarization of further efforts to screen techniques for minefield detection together with recommendations prior to EWG4

ACCOMPLISHMENT MILESTONES - TASK I
(Concluded)

SUBTASK	MILE- STONE	DATE	DESCRIPTION
	M15	July 1, 1979	Summarization of screening efforts to investigate suitability of millimeter and submillimeter radar for minefield detection together with recommendations and bases for decision (see critical decision 2)
	M16	Before Apr. 1, 1979	Conduct Expert Working Group meeting number 2.

CRITICAL DECISIONS - TASK I

SUBTASK	CRITICAL DECISION	DATE	DESCRIPTION
Aerial photography	CD1	July 1, 1979	After SCI and other sources of information regarding capabilities and techniques of aerial photography (visual and near infrared) have been explored, an assessment will be made of its potential for minefield detection. This assessment will be accompanied by initial evaluations of other elements required for decision making such as operational suitability, projected costs and effectiveness, alternatives, etc., so that decisions can be made regarding the priority of this particular effort with respect to other minefield detection efforts.
Millimeter and Submillimeter radar	CD2	July 1, 1979	The technology of millimeter and submillimeter radar has been preliminarily explored for potential capability to detect minefields. Substantial informational gaps have been found. The effort leading to this critical decision is to determine whether the potential offered by this approach justifies further effort and to definitize the nature and extent of this further effort.



PROGRAM SCHEDULE

PROGRAM: Detection of Remote Minefields

TASK II - Preliminary Systems Analysis

REV. DATE

ITEM	1979												1980											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1. Select technical performance criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2. Define conceptual systems																								
Acoustic/seismic (see Sec. 2.2.2)																								
Inferential detection (see Sec. 2.2.2)																								
3. Preliminary systems analysis																								
Acoustic/seismic																								
Inferential detection																								

REMARKS:

Legend:
Forecast
Revision
Actual
Event Milestone

ACCOMPLISHMENT MILESTONES - TASK II

SUBTASK	MILE- STONE	DATE	DESCRIPTION
1.	M1	Mar. 15, 1979	Initial definitization of technical performance criteria preparatory to EWG2
	M2	July 15, 1979	Definitization of technical performance criteria preparatory to EWG3
2.	M3	Mar. 15, 1979	Initial definitization effort on newly identified minefield detection systems preparatory to EWG2
	M4	July 15, 1979	Continued definitization effort on newly identified minefield detection systems preparatory to EWG3
	M5	Jan. 1, 1980	Continued definitization effort on newly identified minefield detection systems preparatory to EWG4
	M6	Mar. 15, 1979	Initial definitization effort on acoustic/seismic minefield detection system together with recommendations preparatory to EWG2
	M7	July 15, 1979	Continued definitization effort on acoustic/seismic minefield detection system together with recommendations preparatory to EWG3 (see critical decision 3)
	M8	Mar. 15, 1979	Initial definitization effort on inferential minefield detection system together with recommendations preparatory to EWG2

ACCOMPLISHMENT MILESTONES - TASK II
(Continued)

SUBTASK	MILE- STONE	DATE	DESCRIPTION
	M9	July 15, 1979	Continued definitization effort on inferential minefield detection system together with recommendations preparatory to EWG3 (see critical decision 4)
	M10	Mar. 15, 1979	Preliminary systems analysis effort on newly definitized minefield detection systems together with recommendations preparatory to EWG2
	M11	July 15, 1979	Continued systems analysis effort on newly definitized minefield detection systems together with recommendations preparatory to EWG3.
	M12	Jan. 1, 1980	Continued systems analysis effort on newly definitized minefield detection systems together with recommendations preparatory to EWG4
	M13	Mar. 15, 1979	Preliminary systems analysis effort on acoustic/seismic minefield detection systems together with recommendations preparatory to EWG2
	M14	July 15, 1979	Continued systems analysis effort on acoustic/seismic minefield detection systems together with recommendations preparatory to EWG3
	M15	Mar. 15, 1979	Preliminary systems analysis effort on inferential minefield detection systems together with recommendations preparatory to EWG2

3.

ACCOMPLISHMENT MILESTONES - TASK II
(Continued)

SUBTASK	MILE- STONE	DATE	DESCRIPTION
5.	M16	July 15, 1979	Continued systems analysis effort on inferential minefield detection systems together with recommendations preparatory to EWG3
	M17	July 15, 1979	Initial definitization of experimental and data acquisition programs for newly defined mine detection systems together with recommendations preparatory to EWG3 and Plan II
	M18	Jan. 1, 1980	Further definitization of experimental and data acquisition programs for newly defined mine detection systems together with recommendations preparatory to EWG4
	M19	July 15, 1979	Initial definitization of experimental and data acquisition programs for acoustic/seismic mine detection systems together with recommendations preparatory to EWG3 and Plan II
	M20	July 15, 1980	Initial definitization of experimental and data acquisition programs for acoustic/seismic mine detection systems together with recommendations preparatory to EWG3 and Plan II
6.	M21	Before Aug. 20	Conduct EWG3
7.	A001		Cost/Performance reports due 7th working day monthly

ACCOMPLISHMENT MILESTONES - TASK II
(Concluded)

SUBTASK	MILE- STONE	DATE	DESCRIPTION
	A002		Progress/Status meeting reports due within 10 days of each progress/status meeting
	A003		Technical Report, Letter progress due 15th of each month
	H3		Plan II due 5 Sept. 1979.

CRITICAL DECISIONS - TASK II

SUBTASK	CRITICAL DECISION	DATE	DESCRIPTION
Acoustic/ Seismic	CD3	July 15, 1979	After selection of technical performance criteria and conceptual systems definition and analysis for the acoustic/seismic minefield detection system together with plans for acquisition for critical data, if needed, a further assessment will be made of its potential for minefield detection. This assessment will form the basis for recommendations for further effort which will be presented together with alternatives as a basis for decision regarding the priority of this particular effort with respect to other minefield detection efforts.
Inferential detection	CD4	July 15, 1979	After selection of technical performance criteria and conceptual systems definition and analysis for the inferential minefield detection system together with plans for acquisition for critical data, if needed, a further assessment will be made of its potential for minefield detection. This assessment will form the basis for recommendations for further effort which will be presented together with alternatives as a basis for decision regarding the priority of this particular effort with respect to other minefield detection efforts.

VERM

PROGRAM SCHEDULE

PROGRAM

Detection of Remote Minefields

TASK III - Conduct Critical Experiments

PEV.

DATE

ITEM	1979							1980								
	J	F	M	A	M	J	J	J	A	M	J	A	S	O	N	D
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Critical Experiments																
Implement test sites																
Site selection																
Establish array																
Critical experiments as defined in Task II, Subtask 5																
Refer to (see Sec. 2.3.1)																
Analysis																

3-24

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DETECTION OF REMOTE MINEFIELDS PROJECT PLAN I(U)
ENVIRONMENTAL RESEARCH INST OF MICHIGAN ANN ARBOR
15 DEC 78 ERIM-138300-4-T DAAK70-78-C-1198

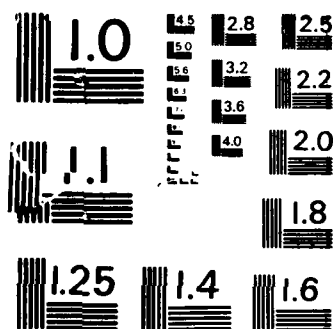
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

PROGRAM SCHEDULE
PROGRAM: Detection of Remote Minofields **TASK III - Conduct Critical Experiments** **REV. DATE**

ITEM	1979							1980						
	J	F	M	A	M	J	J	J	A	M	J	J	A	S
L-band lab. measurements	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Spotlight flight														
Spotlight processing														
Prepare future plans														
Active infrared scanner (see Sec. 2.3.3)														
Instrument acclimations														
1.06 μ laser														

VERM

PROGRAM SCHEDULE

REV.

PROGRAM Detection of Remote Minefields. TASK III - Conduct Critical Experiments DATE

ITEM	1979												1980											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
10.6 μ m laser				3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
																							24	25
																							26	27
																							28	29
Scan mechanism																								
Preparation of system and site																								
System tests																								
Data acquisition																								
1.06 μ m																								
10.6 μ m																								
Range																								

SHEET
3 OF 4

SECRET

PROGRAM SCHEDULE

REV.

PROGRAM Detection of Remote Minefields

TASK III - Conduct Critical Experiment

DATE

ITEM	1979												1980											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Processing and analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Reports and recommendations																								
2. Assemble information from external sources																								
3. Acquire relevant SCI																								
4. Adapt critical data to systems analysis format																								
5. Conduct EAC meeting 4																								
6. Prepare reports, Sept. 1979 through June 1980																								

REMARKS:

REV: SSCG Forecast
 Milestone
 Revision

SHEET
 4 OF 4

ACCOMPLISHMENT MILESTONES - TASK III

SUBTASK	MILE- STONE	DATE	DESCRIPTION
1. Conduct critical experiments	M1	Feb. 15, 1979	Final selection of sites for test arrays
	M2	May 1, 1979	Completion of installation of test arrays for sensor testing
	M3	April 1, 1979	Lab. measurements on mines at L-band by U. of Michigan
	M4	May 20, 1979	Flight test of spotlight radar over test arrays to gather data on minefield detectability
	M5	June 15, 1979	Processing of spotlight radar data
	M6	Sept. 1, 1979	Completion of plans for continued Task III or Task IV effort on spotlight or X-L radar, as input to Project Plan II.
	M7	Feb. 15, 1979	Modify 1.06 μm laser for active scanner tests
	M8	April 1, 1979	Modify 10.6 μm laser for active scanner tests
	M9	April 1, 1979	Modify scan mechanism for active scanner tests
	M10	May 1, 1979	Prepare active scanner system and test site
	M11	May 1, 1979	Test active scanner system operation
	M12	July 15, 1979	Collect experimental data at 1.06 μm
	M13	June 15, 1979	Collect experimental data at 10.6 μm

ACCOMPLISHMENT MILESTONES - TASK III
(Continued)

SUBTASK	MILE- STONE	DATE	DESCRIPTION
	M14	July 15, 1979	Collect experimental data in ranging mode
	M15	Aug. 1, 1979	Complete processing and analysis of active scanner data to determine mine detection performance
	M16	Sept. 1, 1979	Reports and recommendations on active scanner
	M17	Dec. 17, 1979	Reports and recommendations on active scanner preparatory to EWG4
2. External information sources	M18	Mar. 15, 1979	Summarization of initial information assembled from external sources, and resultant recommendations prior to EWG2
	M19	July 15, 1979	Summarization of further external information and resultant recommendations prior to EWG3 and Plan II
	M20	Jan 15, 1980	Summarization of further external information and resultant recommendations prior to EWG4
	M21	July 1, 1980	Summarization of further external information and resultant recommendations prior to EWG5 and Plan III
3. Acquire relevant SCI	M22	Mar. 15, 1979	Summarization of SCI information and resultant recommendations prior to EWG2

ACCOMPLISHMENT MILESTONES - TASK III
(Concluded)

SUBTASK	MILE- STONE	DATE	DESCRIPTION
	M23	July 15, 1979	Summarization of SCI information and resultant recommendations prior to EWGS and Plan II
	M24	Jan. 15, 1980	Summarization of SCI information and resultant recommendations prior to EWG3
	M25	July 1, 1980	Summarization of SCI information and resultant recommendations prior to EWGS and Plan III
5. EWG meeting	M26	Before Feb. 1, 1980	Conduct EWG4
6. Reports	A001		Cost/performance reports due 7th working day monthly
	A002		Progress/status meeting reports due within 10 days of each progress/status meeting
	A003		Technical report letter progress due 15th of each month.

CRITICAL DECISIONS - TASK III

SUBTASK	CRITICAL DECISION	DATE	DESCRIPTION
1. Critical experiments	CD5	Sept. 1, 1979	The experimental program on spotlight radar will become the basis for further definition of work in spotlight radar. Also, processing of spotlight radar with degraded resolution will lead to a decision on the testing of X-L radar.
1. Critical experiments	CD6	Dec. 1, 1979	Critical decisions on the use of the active infrared scanner will be reached on the basis of analysis of rooftop experiments conducted under Task III. These decisions will be concerned with the use of the active scanner at two frequencies and the use of reflectance data and range data.

Verum

PROGRAM SCHEDULE

PROGRAM Detection of Remote Minefields TASK IV - Military Evaluation

REV.
DATE

ITEM	1979												1980															
	J	F	M	A	M	J	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D			
1. Test III output translation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
2. Review technical criteria																												
3. Systems evaluation																												
4. Conduct EMI meeting 5																												
5. Prepare reports, July 1980 through Nov. 1980, Project Plan III and final report																												

3-32

3-32

REMARKS:

REV 2000 Forecast
 IIIIIII Revision
 IIIIIII Actual

Event
 Milestone

SHEET
 1 OF 1

ACCOMPLISHMENT MILESTONES - TASK IV

SUBTASK	MILESTONE	DATE	DESCRIPTION
1. Task III output translation	M1	Jan. 1, 1980	Analysis and interpretation of Task III results preparatory to EWG4 meeting
	M2	July 1, 1980	Analysis and interpretation of Task III results preparatory to EWG5 meeting
2. Revise technical criteria	M3	Jan. 1, 1980	Provide technical criteria for use in evaluating technical opportunities preparatory to EWG4 meeting
	M4	July 1, 1980	Provide technical criteria for use in evaluating technical opportunities preparatory to EWG5 meeting
3. Systems evaluation	M5	Jan. 1, 1980	Systems evaluation of technical opportunities preparatory to EWG4 meeting
	M6	July 1, 1980	Systems evaluation of technical opportunities preparatory to EWG5 meeting
4. EWG meeting	M7	Before July 15, 1980	Conduct EWG5
5. Plan III and reports	M8	Aug. 1, 1980	Submit Project Plan III, recommending future action on mine detection technology beyond present project
	A001		Cost/performance reports due 7th working day monthly

ACCOMPLISHMENT MILESTONES - TASK IV
(Continued)

SUBTASK	MILE- STONE	DATE	DESCRIPTION
	A002		Progress/status meeting reports due within 10 days of each progress/status meeting
	A003		Technical report, letter progress due 15th of each month
	M9	Oct. 31, 1980	Submit draft of final report for review
	M10	Nov. 30, 1980	Submit final report.

are expected to be made is shown on the project schedules by an asterisk. The nature of each of these decisions is further discussed in this section.

Decisions made on the basis of analytical and experimental results of the project will determine the direction of future effort during the project, or in subsequent programs. Unfavorable results of past effort on the technique will result in discontinuance of further effort or redirection of the effort in more promising directions. Favorable results will indicate the desirability of continuing along the same lines as in the past effort.

Once the technical direction of future effort has been defined, priorities will then be established in order to make best use of resources available to the project. These priorities may result in discontinuing work on some useful techniques in favor of others which are believed to have higher potential. Alternatively, the lower priority techniques may be continued but assigned only a limited amount of resources compared to higher priority approaches.

The primary criterion for evaluating the technical capability of individual techniques is the indication of a sufficient probability of detecting mines, minefields, or ancillary equipment or activities. This capability must exist not only under ideal observation conditions but under the actual environmental and tactical conditions likely to be encountered in combat. This detection capability depends on such factors as the sensor resolution and the target and background characteristics (e.g., radar cross section, reflectivity, contrast, etc.).

Consideration of battlefield scenarios in parallel with assessment of technical performance will allow us to take into account other criteria which will affect the ultimate military usefulness of individual techniques.

In making critical decisions, we will thus allow for the known inherent risks of a fully deployed system, including technical and operational risks, susceptibility to countermeasures, possibility of excessive development of life cycle costs, etc.

Aerial Photography. Information gathered through SCI and other sources on specialized types of aerial photographic techniques, including space photography, will be considered under Task I to reach a screening decision concerning possible further effort devoted to any of these opportunities which show promise. It is anticipated that at least some elements of this decision can be made in time for the second EWG meeting in April 1979, with further results sufficient for decision-making (CD1) expected by the third EWG meeting.

Millimeter and Submillimeter Wave Radar. Further Task I investigation of this type of radar will be based on past and current experience at ERIM with this type of system. Preliminary modeling and analysis will result in estimates of mine detectability. The recommendation, expected to be available for the second EWG meeting, will call for either discontinuation of further effort in this direction or further Task II and Task III effort of one or more specific concepts.

Inferential Detection. Interim results of Task II effort on inferential detection methods will be available prior to the second EWG meeting, but a critical decision on the role of inferential detection will have to await results of spotlight radar and active infrared scanner data collection and analysis. A critical decision point will, therefore, be reached at the time of the third EWG meeting and implemented in Plan II.

Acoustic/Seismic Techniques. A critical decision on acoustic/seismic techniques should be made by mid-March, 1979, for review at the second EWG meeting, based on preliminary systems analysis of the concepts discussed in this report. If the preliminary analysis of acoustic and

seismic sensors shows favorable possibilities, the decision could be made to proceed to field tests to acquire acoustic or seismic signatures of minelaying vehicles or operations. The feasibility of the combination of REMBASS sensors and FAE weapons would also require experimental verification.

Spotlight Radar. The experimental program on spotlight radar to be implemented under Task III, Plan I will become the basis for further definition of work in this and related techniques. Depending on experimental findings, the decision might be either to reject the spotlight system and discontinue further effort, or to accept some version of the system for Task IV effort. If necessary, further experiments may be called for to acquire additional data on the spotlight radar.

Performance of the spotlight radar will also have a bearing on decisions concerning the suitability of related types of radar, particularly the X-L dual-frequency, dual-polarization concept. The spotlight radar experiments should lead to adequate information on detectability of individual mines, minefields, etc. to indicate the resolution needed for successful performance of an operational system. If degraded resolution proves to be capable of providing useful indications of mines or minefields, a decision may be made to undertake a flight of the ERIM X-L radar.

Since the flight and data processing of the spotlight radar is expected to be complete by mid-June 1979, the critical decision point for radar work on spotlight or X-L band systems will be made in time for incorporation in Plan II.

Active Infrared Scanner. Critical decisions on the use of the active infrared scanner will be reached on the basis of analysis of the experiments described in this report. Since several options for use of the active scanner data exist (i.e., 1.06 μm , 10.6 μm , and ranging data), the decisions will be concerned with the performance of each of

these options. It is anticipated that the resulting decision can be made on the basis of a preliminary look at the test data, without completing a full analysis of the data.

Favorable results would lead to a decision to proceed with full analysis of the data collected as described in Section 2.3.2. It might also be decided to conduct a flight test of the active scanner over the test arrays to confirm experimental results with airborne equipment, as a logical next step in the development and application of the technique. The decision on the use of the scanner (CD6) can be made by December 1, 1979 in time for the fourth EWG meeting.

Other Techniques. In addition to the specific techniques discussed above, it is anticipated that the effort under Task I directed toward consideration of other techniques not yet identified will lead to critical decisions in time for incorporation in Plan II. The nature of these critical decisions and the alternatives available for consideration will be clarified on the basis of the technical results of the Task I effort.

3.4 RESOURCE REQUIREMENTS

This section summarizes the requirements of the Plan I program for personnel, facilities, and equipment, materials and services.

In coordination with the preparation of Plan I, necessary arrangements have been made through management planning and standard scheduling procedures to assure that the necessary resources will be assigned to the project when scheduled.

3.4.1 PERSONNEL RESOURCES

The technical effort defined in Section 2 will require assignment of technical personnel to three of the four project tasks during Plan I. Personnel with backgrounds suitable for work on these tasks have been

identified and tentative commitments have been made for their availability when needed. Upon approval of Plan I by the sponsor, these commitments will be made firm for the personnel required to perform the tasks of Plan I.

Table 3-3 shows the skill levels to be assigned to the individual tasks. Further detailed information on personnel assignments will be prepared after the approval of Plan I.

3.4.2 FACILITIES AND EQUIPMENT

Table 3- 4 shows the major facilities and items of equipment needed to perform the work defined in Plan I.

3.4.3 MATERIALS AND SERVICES

Table 3-5 shows the materials and services, including subcontracts, needed to perform the work defined in Plan I.

TABLE 3-3. PERSONNEL REQUIREMENTS BY TASK

<u>Personnel</u>	<u>Task I</u>	<u>Task II</u>	<u>Task III</u>
Senior Research Engineer	X	X	X
Research Engineer	X	X	X
Associate Research Engineer			X
Assistant Research Engineer			
Research Associate			X
Research Assistant			
Technical Associate			X
Senior Research Technician			X
Research Technician			X
Assistant in Research			
Hourly Professional			X
Nonhourly Professional			
Photographer			X
Graphics Technician			
Pilot			X
Aircraft Technician			X

TABLE 3-4. FACILITIES AND EQUIPMENT

		<u>Source</u>
<u>Test Site:</u>		
2 or 3	Test site (150m x 300m each)	ERIM
	Test site preparation	
2000	Inert mines (metal and plastics)	GFE
	Barbed wire fence	
	Corner reflectors	ERIM
1	Minelaying vehicle	GFE
1	Truck (fitted with simulated mine-laying chutes)	ERIM
1	Minelaying cord	ERIM
3-4	Military trucks	GFE
	Ground truth instrumentation (weather, soil moisture, cameras, etc.)	ERIM
<u>Radar Tests:</u>		
	CV580 aircraft	ERIM
	Spotlight radar	ERIM
	Image dissector facility	ERIM
	Digital computer	ERIM
<u>Active Scanner Tests:</u>		
1	AVD-4 active scanner modified to incorporate 10.6 μ m source	ERIM
	Rooftop instrumentation facility	ERIM
	11/45 digital computer	ERIM
	Amdahl 470 digital computer	Univ. of Michigan
	Image processing equipment	ERIM

TABLE 3-5. MATERIALS AND SERVICES

Radar Tests

L-band measurements (subcontract to Univ. of Michigan)	\$5,000
Andrew Maffett, 30 days consulting time (subcontract)	7,800
Expert Working Group, 40 days consulting time	
Computer time	178
Aircraft Operation	2,090
Miscellaneous materials and supplies	2,400

Active Scanner Tests

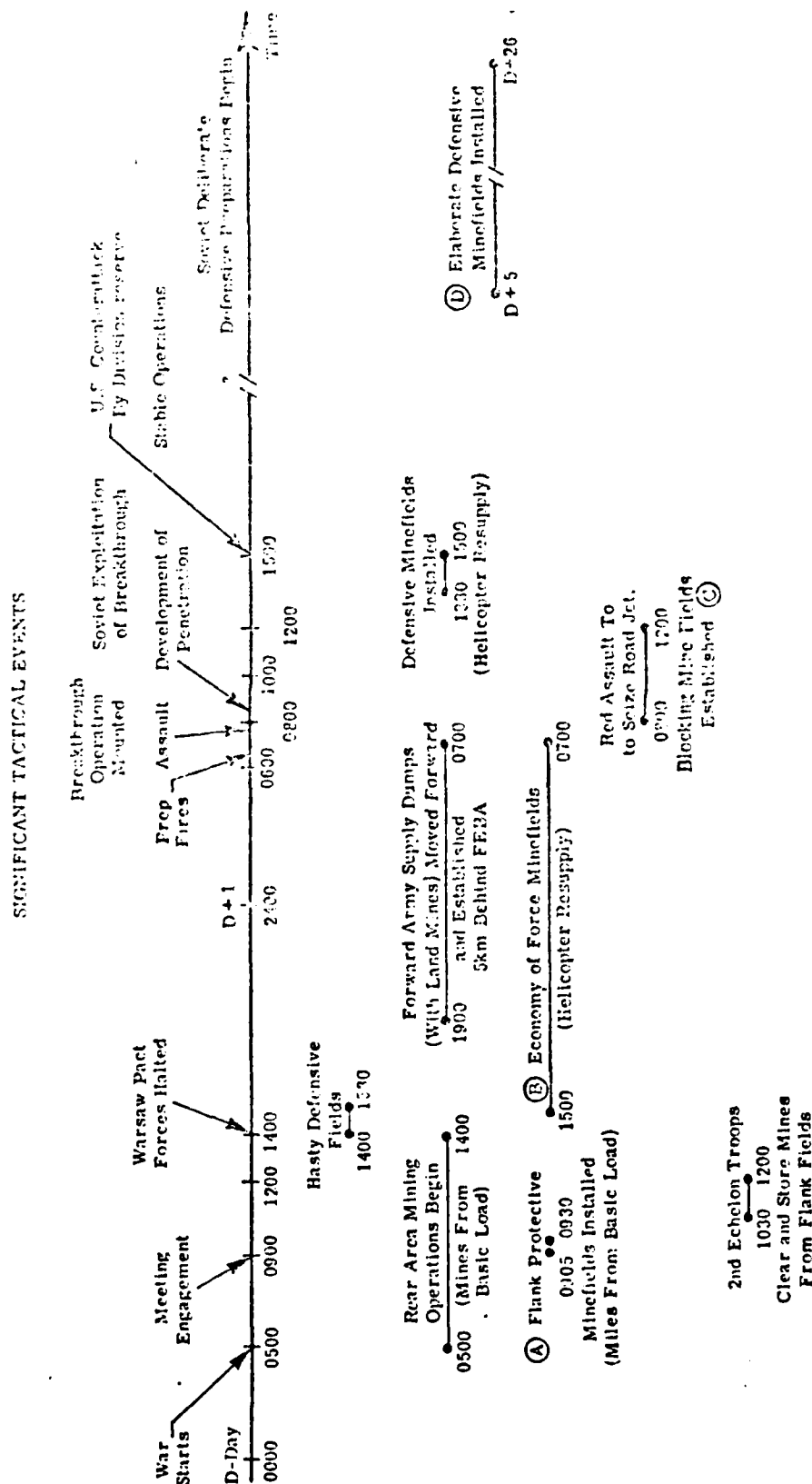
1/2 hr, Amdahl 470 digital computer	
Materials	\$4,000

APPENDIX A
BATTLEFIELD SCENARIOS AND TACTICS

This appendix gives further information on anticipated battlefield scenarios likely to be encountered in the Eastern European Theater. This information was supplied by Braddock, Dunn, and McDonald, the system contractor on remote minefield detection.

Figure A.1 exhibits a timeline for Soviet land mine warfare operations. Keyed to this diagram are Figures A.2 through A.9 giving details of the tactical situation and objectives, minefield specifications and location, etc. The data from this appendix are being used in assessment of specific technical approaches to the minefield detection problem.

FIGURE A.1 TIMELINE FOR SOVIET LANDMINE WARFARE OPERATIONS
(PER SOVIET DIVISION - EUROPEAN SCENARIO)

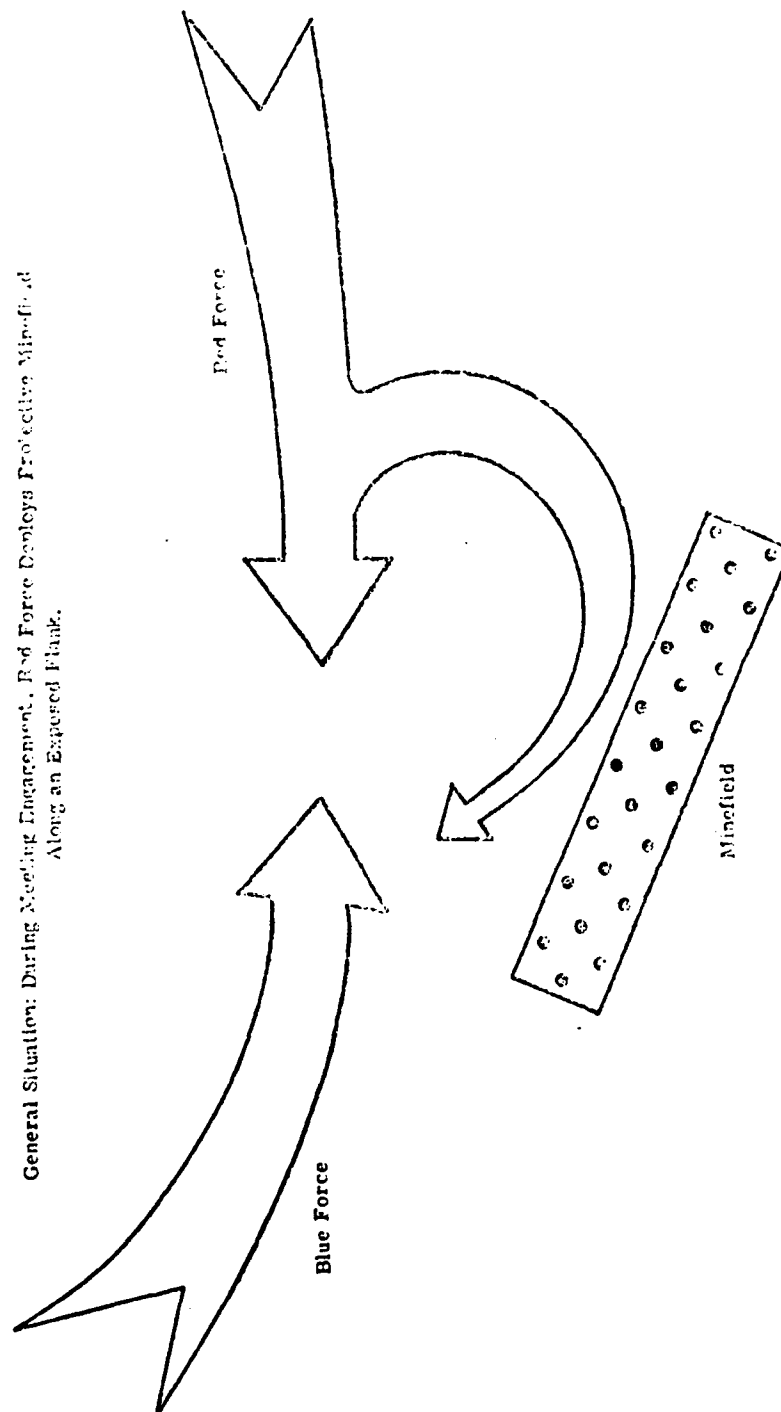


SOVIET LANDMINE AND SUPPLY OPERATIONS

FIGURE A.2 GENERAL DESCRIPTION OF LANDMINE WARFARE SITUATION (A)

Landmine Warfare Event: Minefield to Provide Protection to Exposed Flank

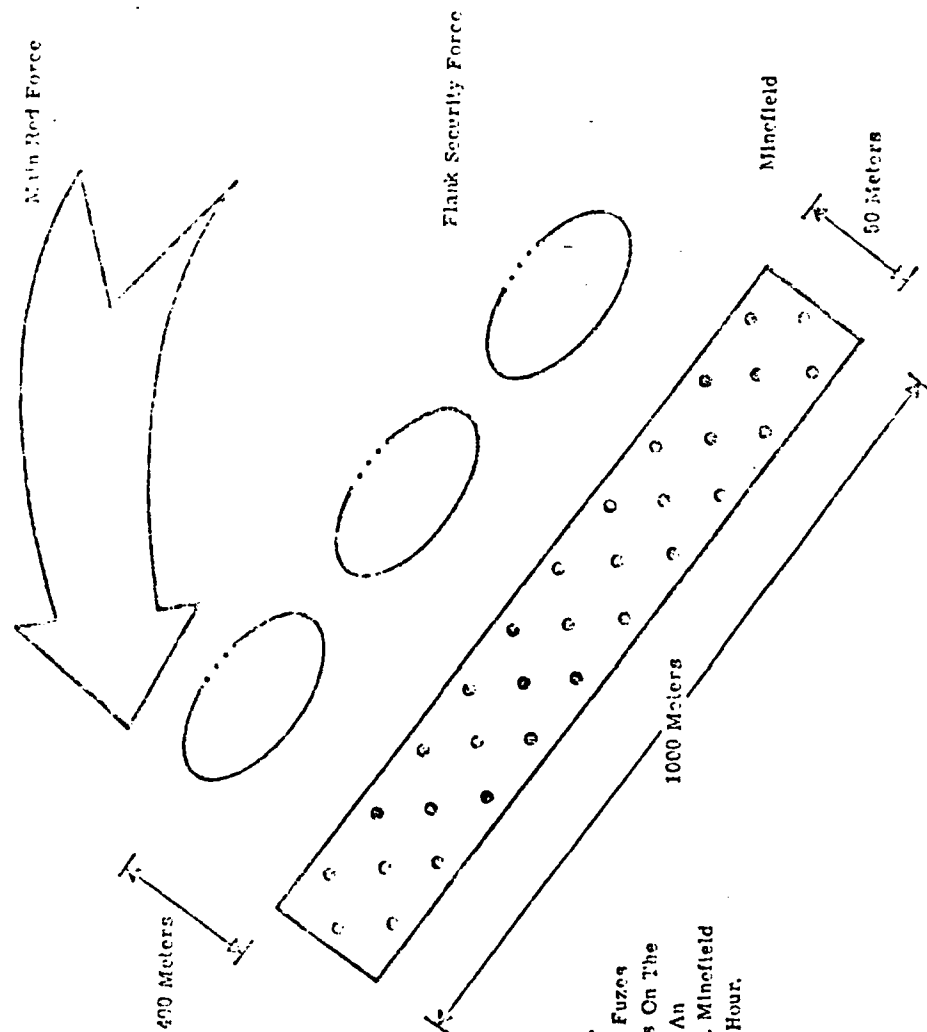
General Situation: During Meeting Engagement, Red Force Deploys Protective Minefield Along an Exposed Flank.



Significant Times:

- Minefield Installed: 0900 - 0930 on D-Day
- Minefield Encountered: 0950 on D-Day
- Minefield Cleared by Soviet 2nd Echelon Troops: 1030 on D-Day
- Elapsed Time Between Minefield Installation and Encounter: 20 Minutes
- Length of Time Minefield in Place: 1 Hour

FIGURE A.2 CHARACTERISTICS OF FLANK PROTECTION MINEFIELD



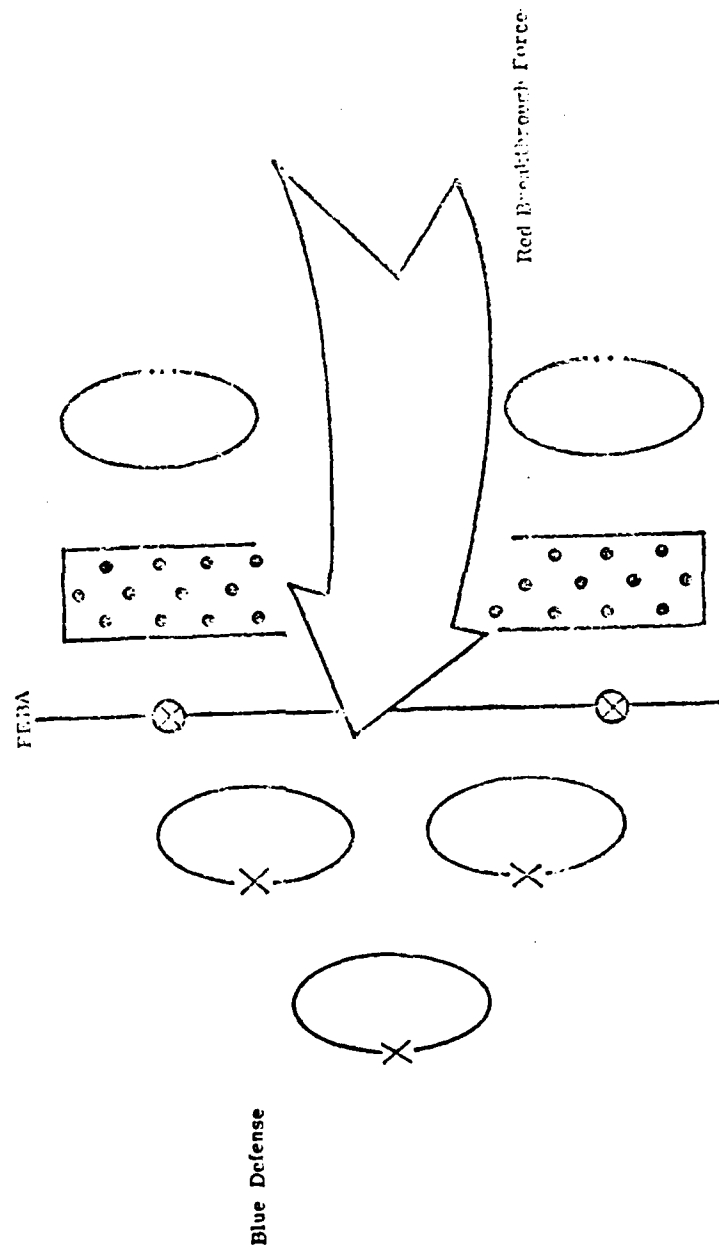
MINEFIELD SPECIFICATIONS

- 545 FM 60 Mines With Metallic Pressure Fuzes Installed using 3GNIZ (50 Layer) in 3 Rows On The Surface. Rows Are 25m Apart, Mines Are An Average of 5.5 Meters Apart in Each Row. Minefield to Remain in Place For Approximately 1 Hour.

FIGURE A.4 CENTRAL DESCRIPTION OF LANDMINE WARFARE SITUATION ④

Landmine Warfare Event: Minefield to Protect Shoulders During A Breakthrough

General Situation: During The Breakthrough, Red Forces Deploy Minefields On The Shoulders Of The Breakthrough Sector As An Economy Of Force Measure



Significant Times:

- Minefield Installed: 1800-1900 D-Day
- Minefield Encountered: 1000 D+1
- Elapsed Time Between Installation and Encounter: 15 Hours
- Minefield Cleared By Soviet 2nd Echelon Troops: 1500 D+1
- Length Of Time Minefield In Place: 20 Hours

FIGURE A.5 CHARACTERISTICS OF ABBETTED TO PROTECT SEVERAL OF THE BREAKTHROUGH SECTION (B)

FIGURE A.6 GENERAL DESCRIPTION OF LANDMINE WARFARE SITUATION

Landmine Warfare: From Battlefield To Block Movement Of Refugees

General Situation: Air Assault Force Seizes Critical Road Junction And Damages Bridge Prior To A Meeting Action

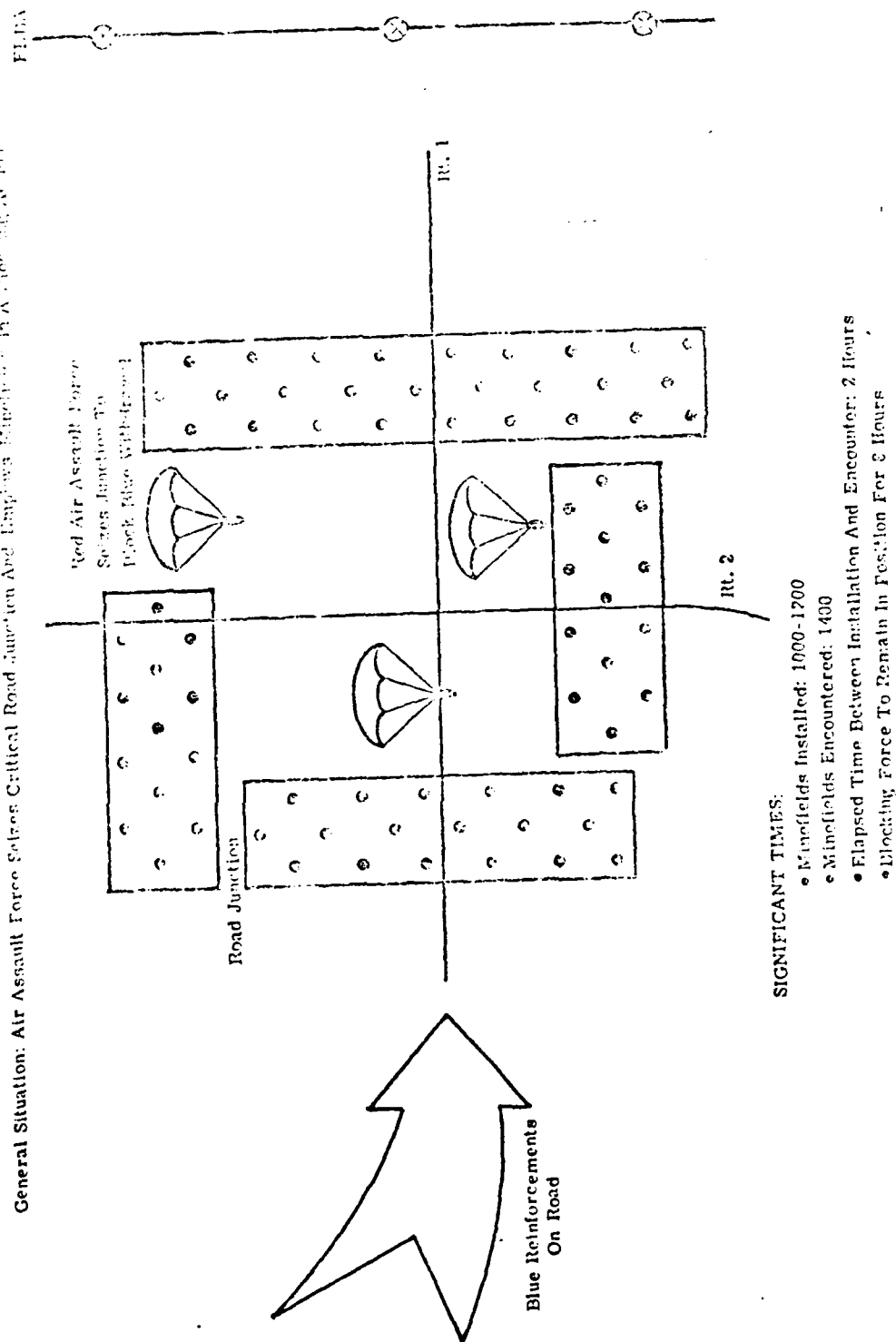


FIGURE A.7 CHARACTERISTICS OF MINEFIELDS TO PLACER MOVEMENT
OF REINFORCEMENTS ①

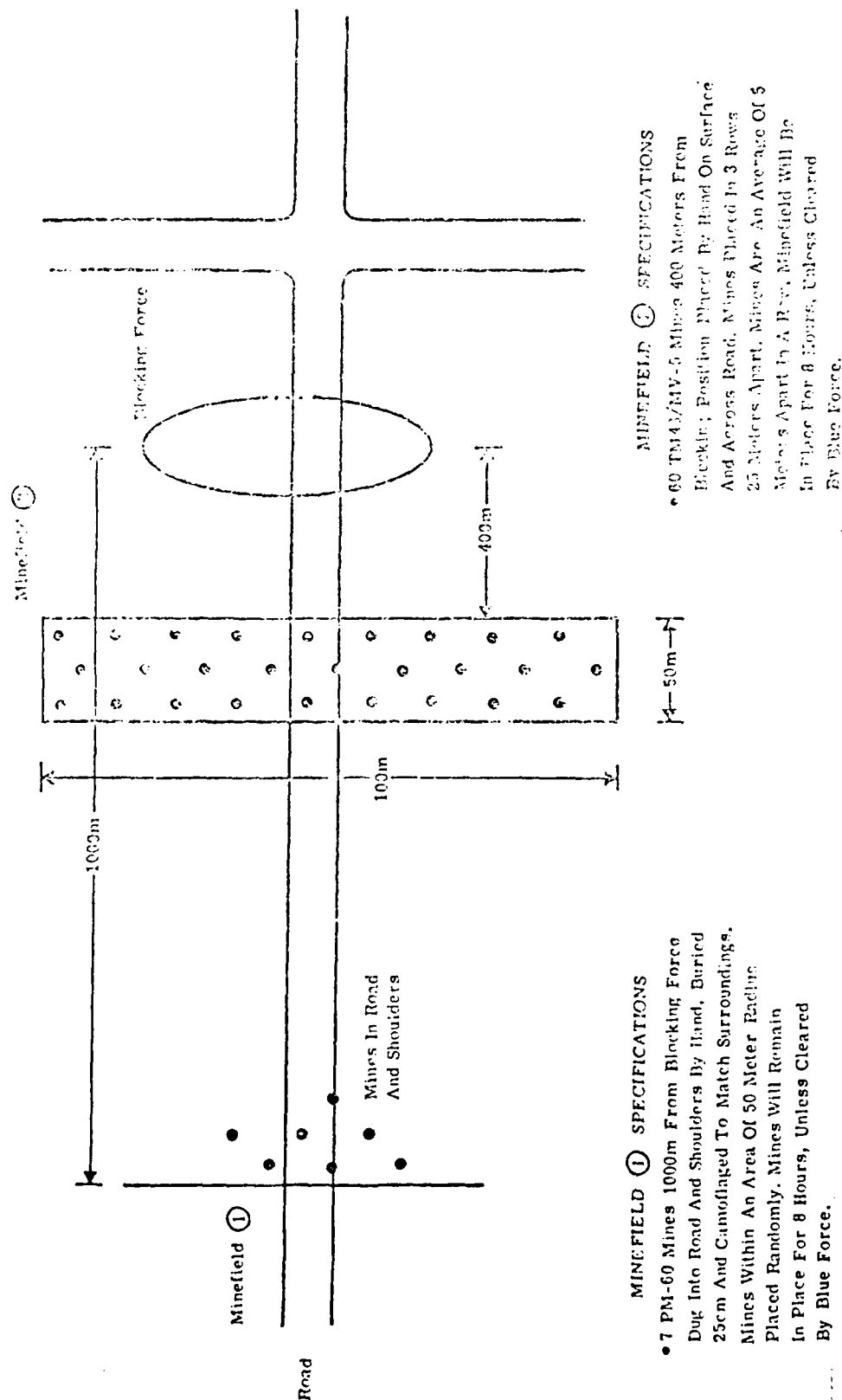
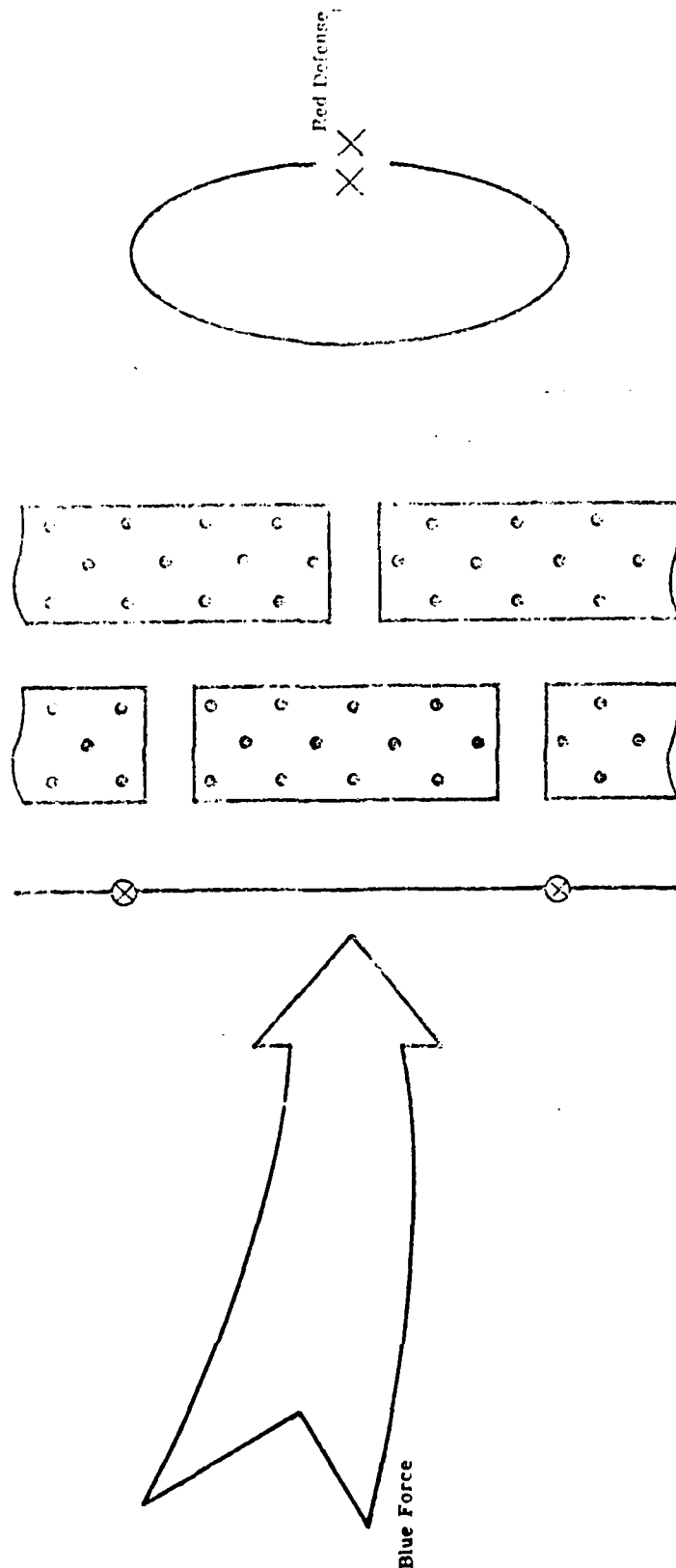


FIGURE A.8 GENERAL DESCRIPTION OF LANDMINE WARFARE SITUATION ⑧

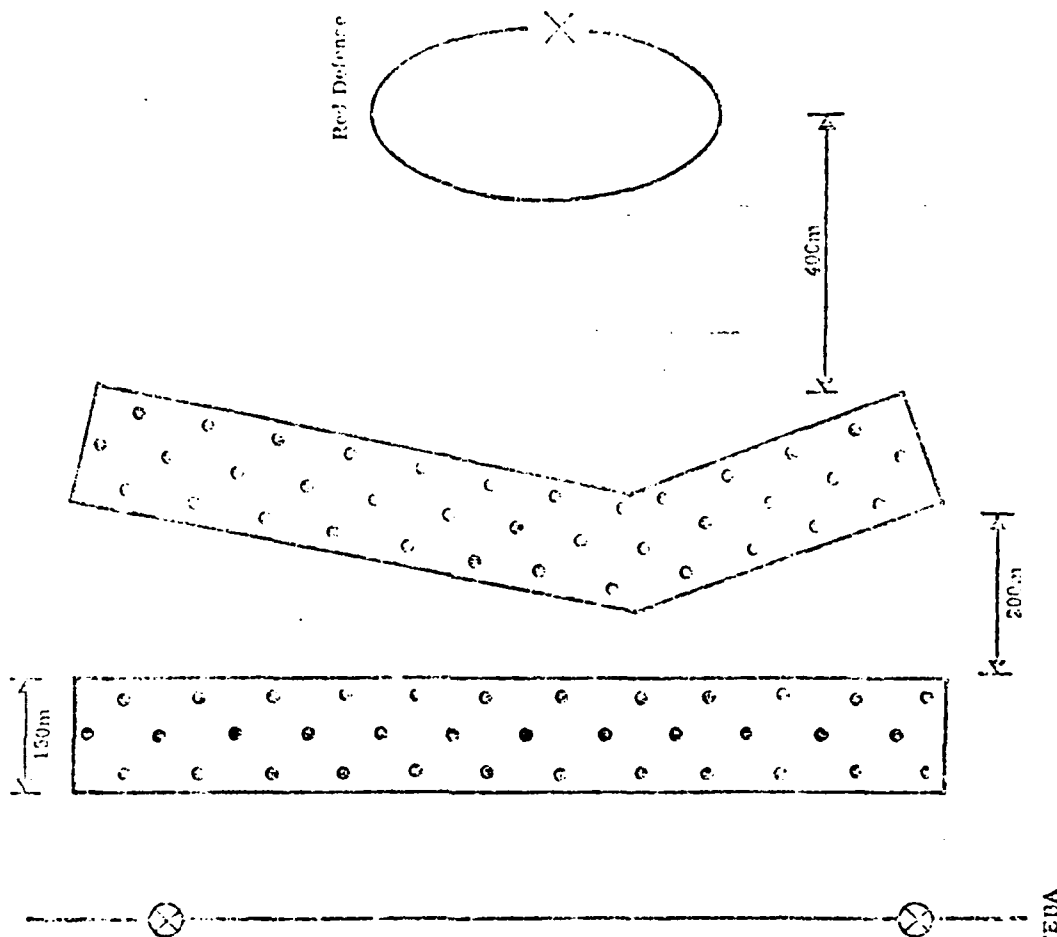
Landmine Warfare Event: Minefield To Support Prepared Defenses
 General Situation: Soviets Install Deliberate Defensive Positions With Mine Augmentation



SIGNIFICANT TIMES:

- Minefield Installed D+5 To D+26
- Minefield Encountered D+30
- Average Time Between Installation And Encounter 14 Days
- Minefield Will Not Be Cleared By Soviets

FIGURE A.9 CHARACTERISTICS OF HEAVY DEFENSIVE MINEFIELD



MINEFIELD SPECIFICATIONS

- 545 TM46/MV-5 Mines Are Installed in Each Minefield By 3 Cargo Trucks (ZIL-157) Equipped With Chutes, Each Row Is 50 Meters Apart, Mines Are Placed An Average of Every 5.5 Meters, Buried 25cm Deep and Camouflaged to Match Surrounding Ground. Minefield Will Not Be Cleared By Soviets.

END

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